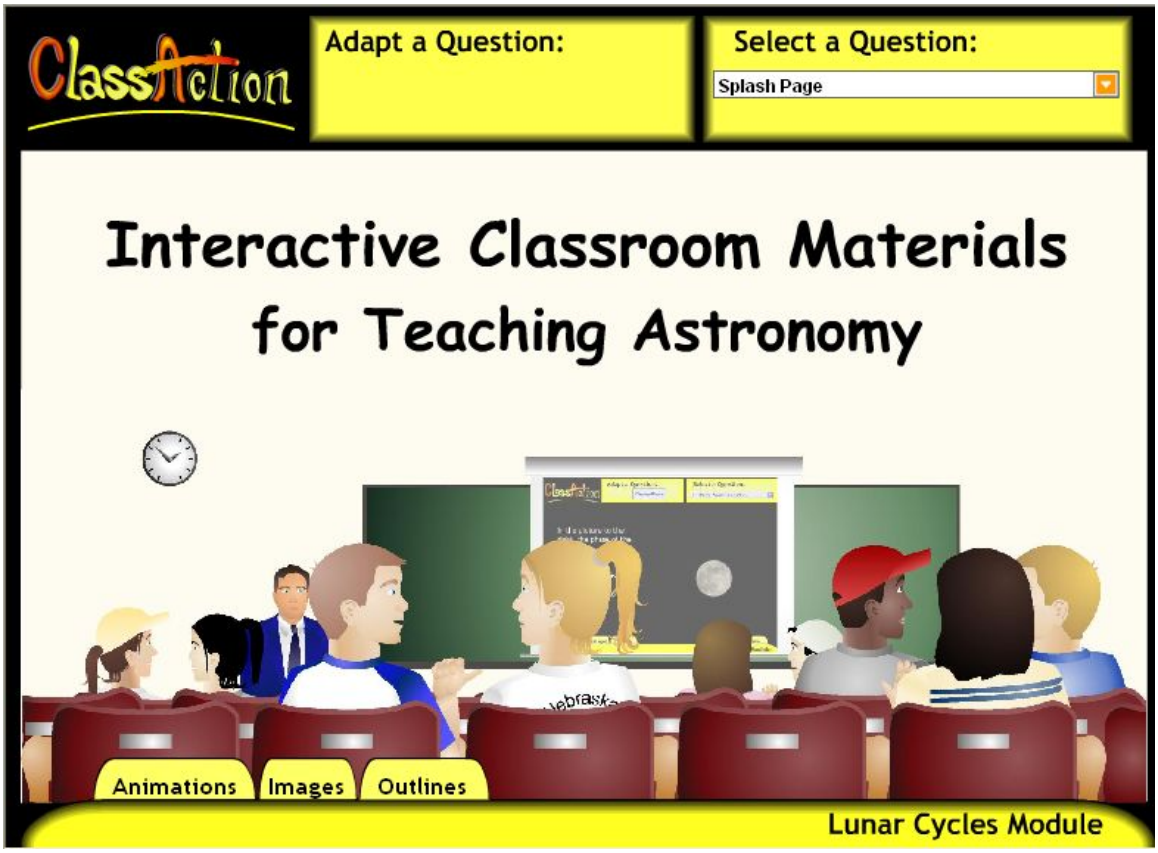
ClassAction: Lunar Cycles Module Instructor's Manual



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Section 1: *Warm-up Questions*

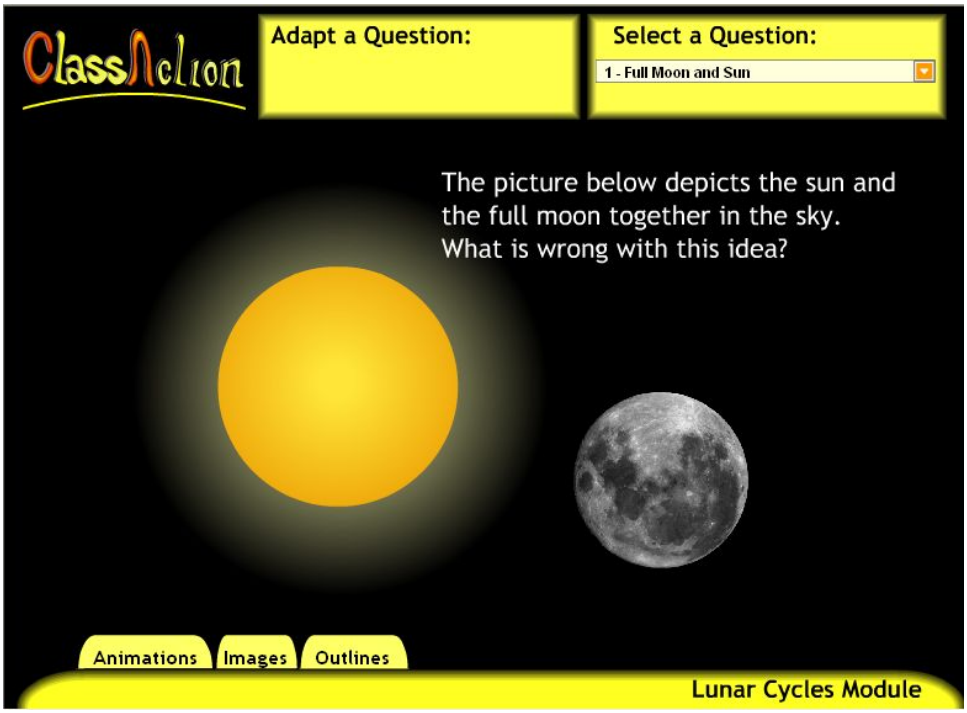
This section contains warm-up questions. These questions are single concept based and therefore generally straightforward to answer.

It is recommended that these questions be projected during the few minutes immediately preceding class.

Teaching suggestions, and possibly hints, are provided for every question.

A degree of difficulty (1 – 5; 1 being easy and 5 being difficult) is also provided for every question.

Full Moon and Sun



Key Concept: Phases of Moon

Secondary Concepts: Causes for Phases of the Moon

Description:
The image above displays the Sun and the full moon adjacent to each other in the daytime sky. Students should determine if there is anything wrong with the picture.

Answer:
For the Moon to be full it must be opposite the Sun in the sky. Thus: *There is no way the full moon can be adjacent to the Sun in the sky.* In fact, the Moon would be new moon if adjacent to the Sun in the sky. A second (and more subtle) answer is that the angular sizes of the sun and moon aren't correct. They should be very close to the same size, about half a degree. Even when the moon is near apogee, it isn't as small compared to the sun as shown here.

Suggestions:
Recommended animations: 3 View Simulator.

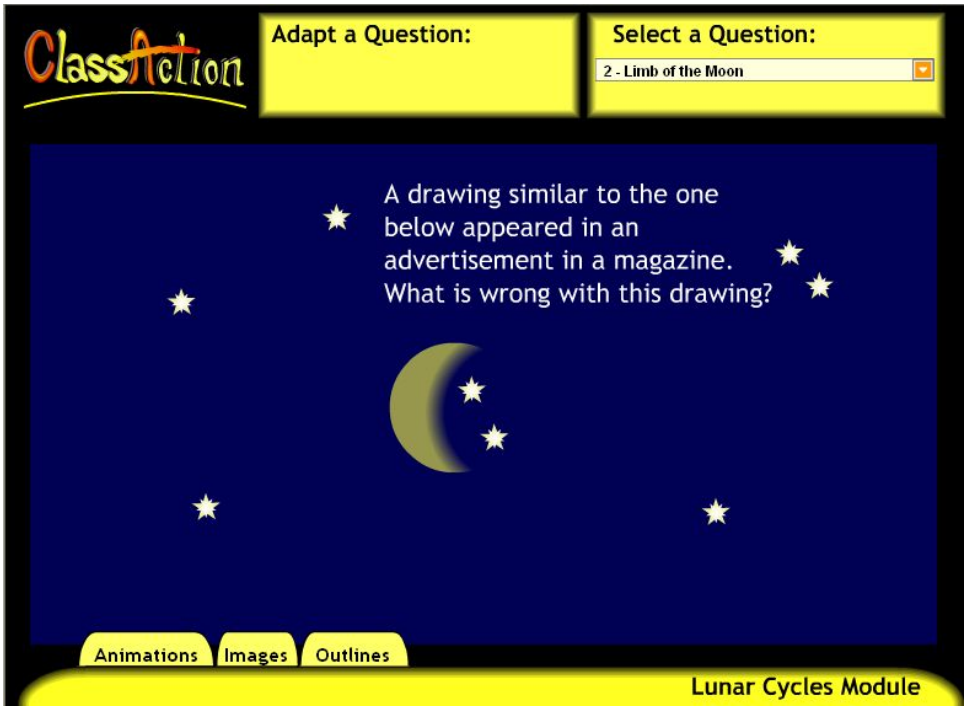
Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

A good follow-up question would be to ask what phase should actually be shown in the picture if the Sun and the Moon are adjacent to each other in the sky.

Hints:
Perhaps ask the students which is closer to the Earth, the Moon or Sun. This may help them better imagine the configuration between the Sun, Earth, and Moon.

Difficulty: 2

Limb of the Moon



Key Concept: Causes for Phases of the Moon

Secondary Concept: Shape of the Moon

Description:
The image above displays a crescent moon with a couple of stars near, or "inside," the crescent. Students should determine if there is anything wrong with the picture.

Answer:
The moon is a spherical object and has a circular projection on the sky, thus:

The two stars shown near the moon should be obscured by the part of the moon in shadow.

Suggestions:
Recommended animations: Lunar Phase Vocabulary.

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Hints:
Perhaps ask the students which is closer to the Earth, the Moon or the stars. This may help them better imagine the configuration between the Earth, Moon, and stars.

Also, perhaps ask them what the shape of the Moon is and how would that project itself on the sky.

Finally, perhaps identify the phase (waning crescent) and ask them the cause of that phase (or any of the phases).

Difficulty: 2

Section 2: *General Questions*

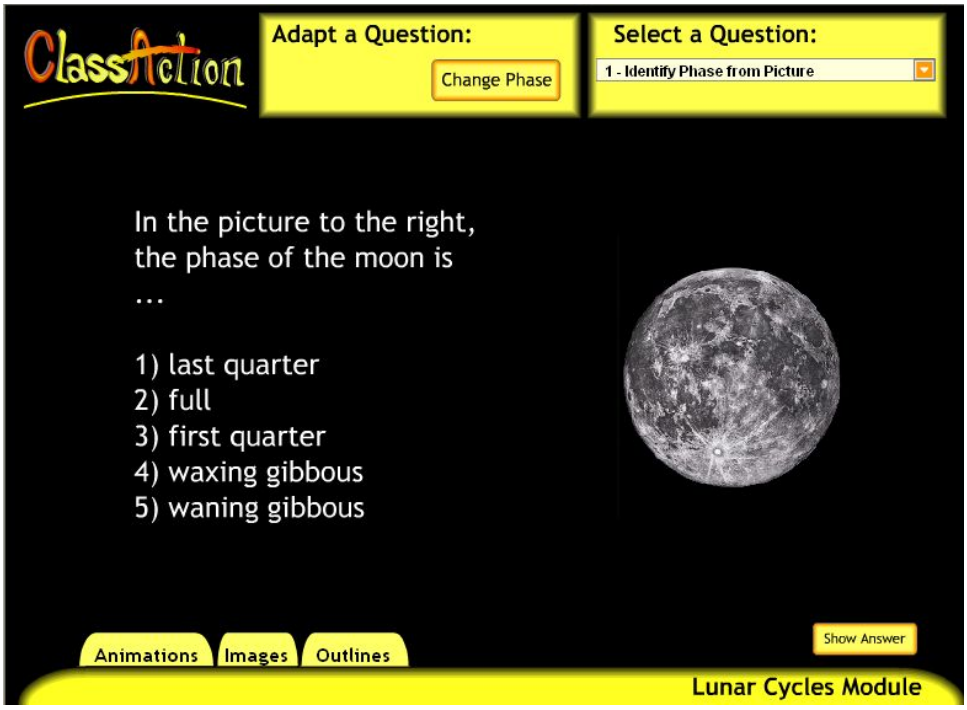
This section contains general astronomy questions that are straightforward applications of the material. These questions are designed to basically test 1 – 2 astronomical concepts, and while not necessarily easy, the concepts being tested are in the same context in which they are generally covered in a lecture and/or textbook.

It is recommended that the think-pair-share method be employed for these questions.

Teaching suggestions, and possibly hints, are provided for every question.

A degree of difficulty (1 – 5; 1 being easy and 5 being difficult) is also provided for every question.

Phases of the Moon 1



Key Concept: Phases of the Moon

Secondary Concepts: Causes for the Phases of the Moon

Description:
The image displays the Moon at a certain lunar phase. Students should identify the lunar phase from the image.

Suggestions:
There are 8 different adaptations to the question, therefore the instructor could identify one or two lunar phases (and explain how they were identified) and use the think-pair-share method with the remaining adaptations.

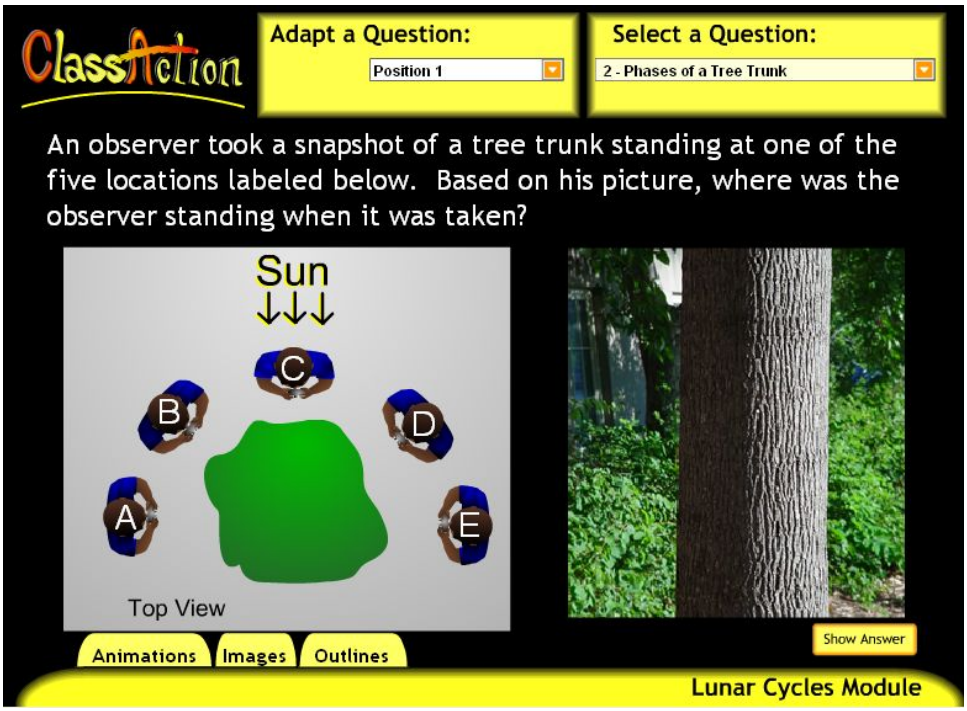
Recommended animations: The Lunar Phases Simulator.

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Recommended outlines: Phases of the Moon.

Difficulty: 1

Phases of a Tree Trunk



Key Concept: Causes for the Phases of the Moon

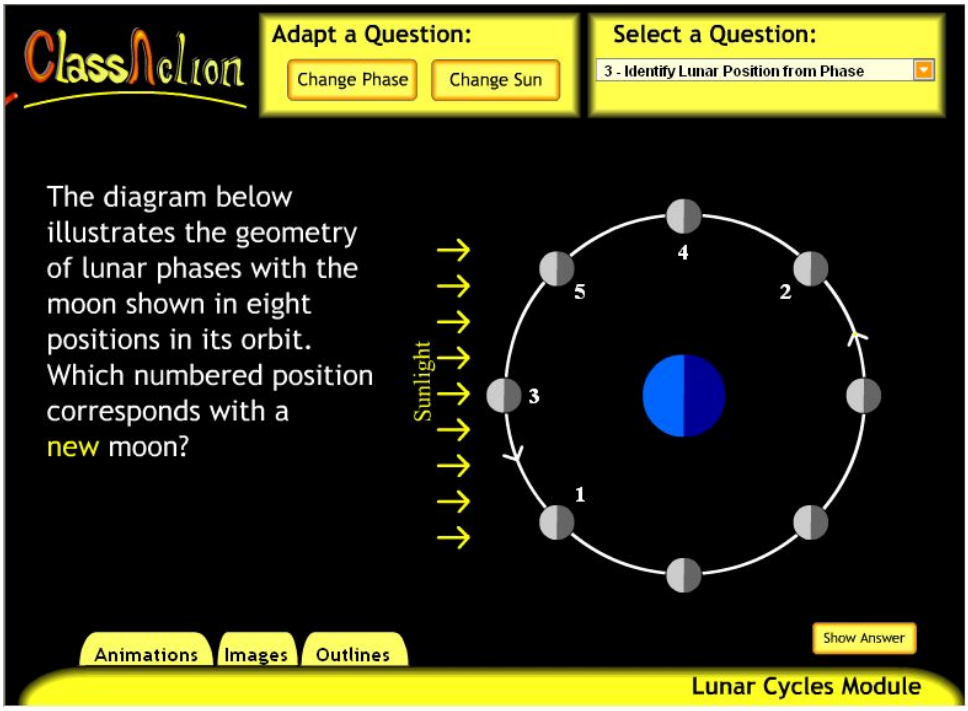
Description:
The image above displays on the left a top view of a tree, 5 different possible locations an observer, and direction of the incident rays of sunlight. On the right is an actual photograph of the tree trunk taken by an observer at one of the locations around the tree. Students should determine from which location the observer took the photo presented.

Suggestions:
There are 5 different adaptations to the question, therefore the instructor could identify one or two "tree phases" (and explain how they were identified) and use the think-pair-share method with the remaining adaptations.

Recommended animations: Basketball Phases Simulator

Difficulty: 2

Phases of the Moon II



Key Concept: Phases of the Moon

Secondary Concepts: Causes for the Phases of the Moon

Description:
The image above displays the Earth, the Moon at eight different possible locations in its orbit around the Earth, and a selected incident direction of sunlight. Students should determine which location corresponds to the phase of the moon selected for the question asked.

Suggestions:
Since both the phase of the Moon and the direction of incident sunlight can be varied, there are many different adaptations to the question. The instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

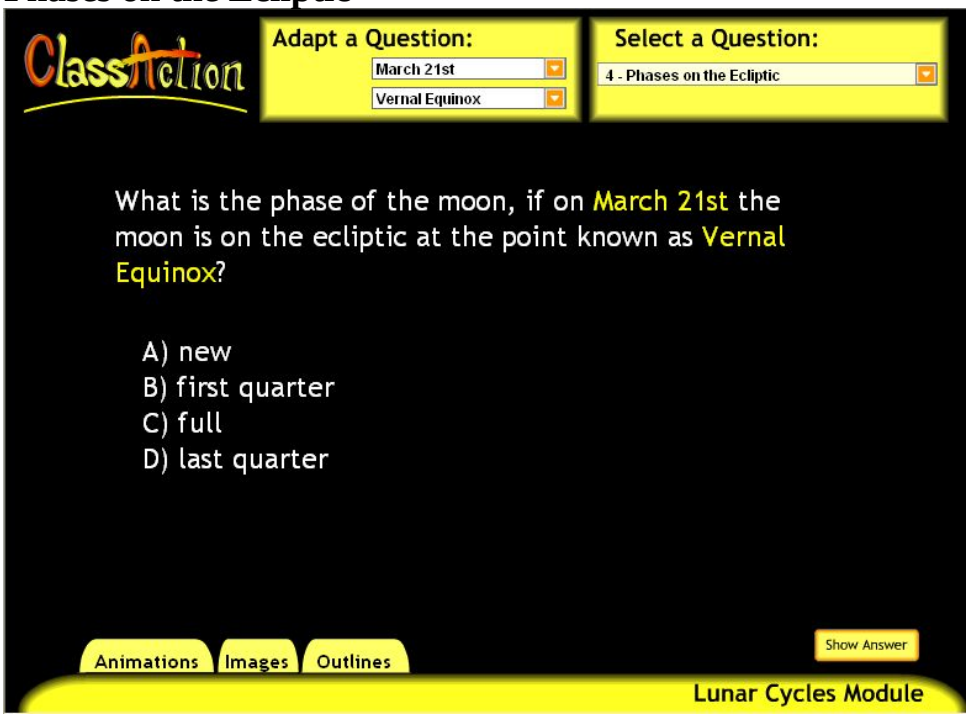
Recommended animations: Lunar Phases Simulator.

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Recommended outlines: Phases of the Moon.

Difficulty: 3

Phases on the Ecliptic



Key Concept: Phases of the Moon

Secondary Concepts: Ecliptic; Celestial Sphere; Seasons; Equinox and Solstice

Description:
A question is presented that indicates the position of the Earth in its orbit with respect the Sun (based upon the selected date) and the position of the Moon in its orbit with respect to the Earth (based upon the selected point on the ecliptic). Students should determine what phase of the Moon would occur for the selections made.

Answer:
The equinoxes and solstices are often misunderstood as being exclusively certain days of the year, but in actuality they are locations on the celestial sphere. For example, when it is the "summer solstice" during the year, this simply means that the Sun appears to occupy a specific location on the celestial sphere (with a specific set of background stars) on that day (Jun. 21st). The Sun occupying that location also corresponds with when the North Pole of the Earth is tipped directly towards the Sun, which signals the beginning of the summer season on Earth. When the Moon is said to be at the "summer solstice," this means it occupies that same location on the celestial sphere with the corresponding set of background stars behind it. To determine the lunar phase, the orientation of the Sun, Earth, and location on the celestial sphere should be determined based upon the selected date, and then the Moon should be placed in a proper orientation to them based upon the location in space provided with the selected equinox or solstice. Thus:

On Mar. 21st, the lunar phase is new / 1st quarter / full / 3rd quarter when the Moon is on the vernal equinox / summer solstice / autumnal equinox / winter solstice.
On Jun. 21st, the lunar phase is new / 1st quarter / full / 3rd quarter when the Moon is on the summer solstice / autumnal equinox / winter solstice / vernal equinox.
On Sept. 21st, the lunar phase is new / 1st quarter / full / 3rd quarter when the Moon is on the autumnal equinox / winter solstice / vernal equinox / summer solstice.

On Dec. 21st, the lunar phase is new / 1st quarter / full / 3rd quarter when the Moon is on the winter solstice / vernal equinox / summer solstice / autumnal equinox.

Suggestions:
There are 16 different adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Lunar Phases Simulator.

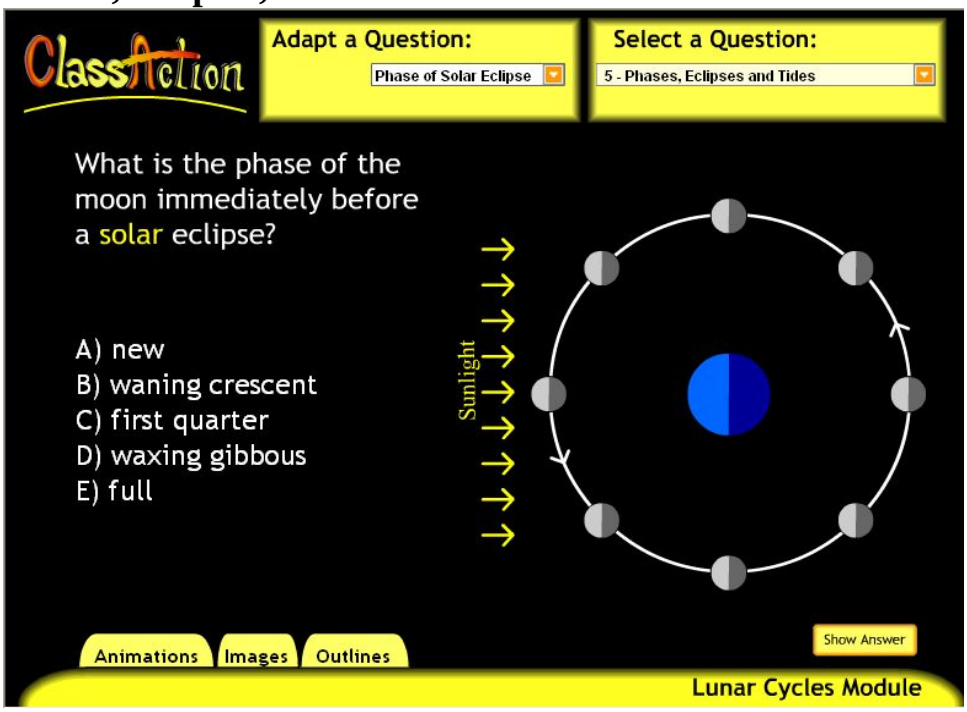
Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Recommended outlines: Phases of the Moon.

Hints:
Perhaps ask the students to draw the Earth in its orbit around the Sun and the locations corresponding to Jun. 21st, Sept. 21st, Dec. 21st, and Mar. 21st; then have them identify the locations of the equinoxes and solstices based upon their drawing.

Difficulty: 4

Phases, Eclipses, and Tides



Key Concepts: Phases of the Moon

Secondary concepts: Solar and Lunar Eclipse; Cause of Tides on Earth

Description:
The image above displays the Earth, the Moon at eight different possible locations in its orbit around the Earth, and the incident direction of sunlight. Students should determine which phase of the Moon corresponds to the eclipse or tide configuration selected.

Answer:
A solar eclipse can only happen during the new moon phase. A lunar eclipse can only happen at or near the full moon phase. A spring tide occurs when the Sun, Moon, and Earth are aligned; therefore, spring tides correspond to the new and full moon phases. A neap tide occurs when the Sun, Moon, and Earth form a right angle; therefore, neap tides correspond to the 1st and 3rd quarter phases. Thus:

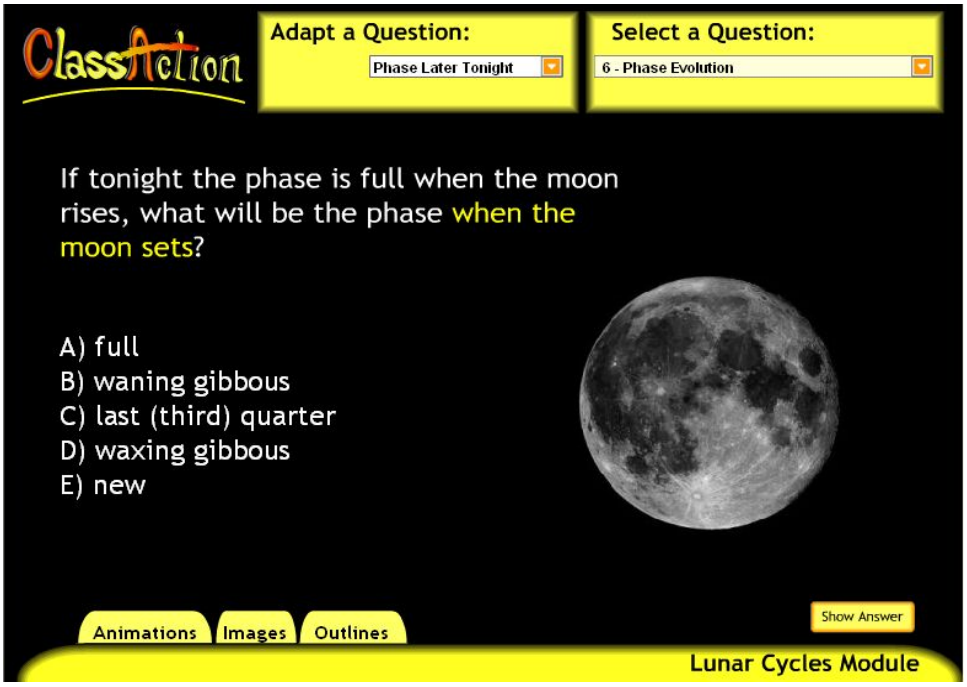
The phase of the Moon immediately before a solar eclipse would be the new moon phase.
The phase of the Moon immediately before a lunar eclipse would be the full moon phase.
The phase of the Moon associated with the strongest tides would be the new moon phase.
The phase of the Moon associated with the weakest tides would be the 1st quarter phase.

Suggestions:
There are 4 different adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: 3 Views Simulator; Moon Inclination Simulator; Tidal Bulge Simulator.

Difficulty: 3

Phase Evolution



Key Concept: Phases of the Moon

Secondary Concepts: Synodic period; Sidereal period

Description:
The image displays the Moon at a certain lunar phase. Students should predict the future lunar phase based upon the amount of time selected.

Answer:
The synodic period of the Moon (from one phase cycle to the next) is 29.5 days; therefore, the time in-between the eight main phases of the Moon must be 29.5 / 8 ≈ 4 days. Also, the Moon moves in its orbit at a rate of about 13^o per day with respect to the stars. Since the Moon moves, the Earth will have to rotate this extra angular amount per day to see the Moon at the same position relative to a given horizon. Since it takes the Earth about 4 minutes to rotate 1^o, rotating an extra 13^o corresponds to about 50 minutes, thus the Moon appears to rise later each day by about 50 minutes. Thus:

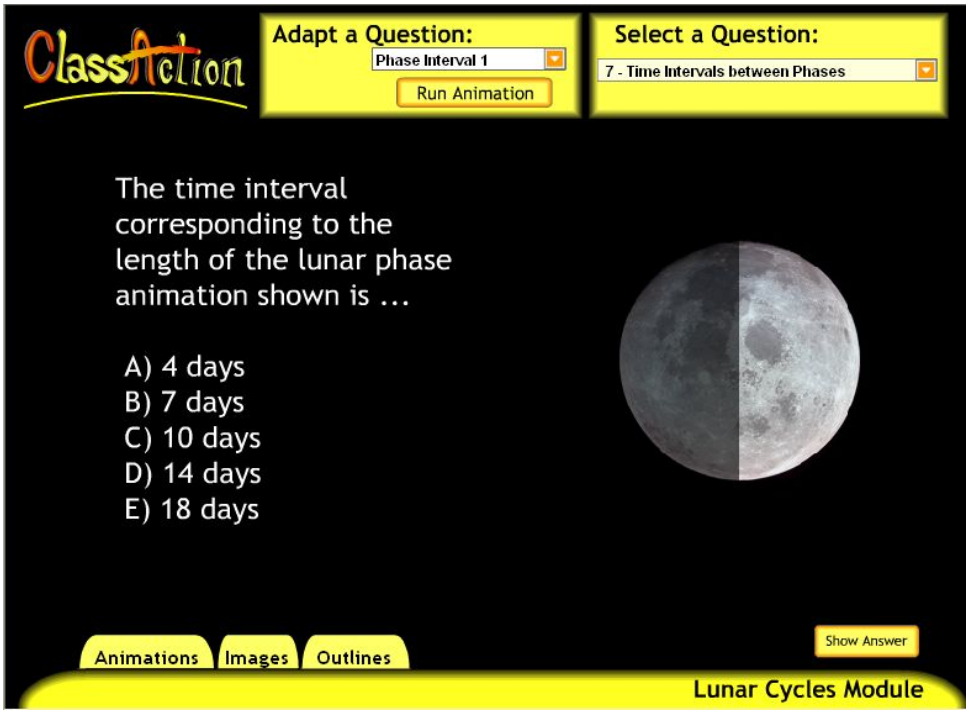
Over the course of one night (from moon rise to moon set) the phase of the Moon will not change significantly and a full moon will remain a full moon.
Four days later a full moon will become a waning gibbous moon.
One week later (about 8 days) a full moon will become a 3rd quarter moon.
If the full moon rises at 6:00 p.m. tonight, then it should rise 50 minutes later, or 6:50 p.m., tomorrow.

Suggestions:
There are 4 different adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: 3 View Simulator; Lunar Phases Simulator.

Difficulty: 3

Time Intervals between Phases



Key Concept: Phases of the Moon

Secondary Concept: Synodic period

Description:
The image displays the Moon at a certain initial lunar phase. As the animation proceeds, the image will gradually change to a final lunar phase corresponding to the phase interval selected. Students should determine the amount of time necessary for a selected phase interval.

Answer:
The synodic period of the Moon (from one phase cycle to the next) is 29.5 days; therefore, the time in-between the eight main phases of the Moon must be 29.5 / 8 ≈ 4 days. Thus:

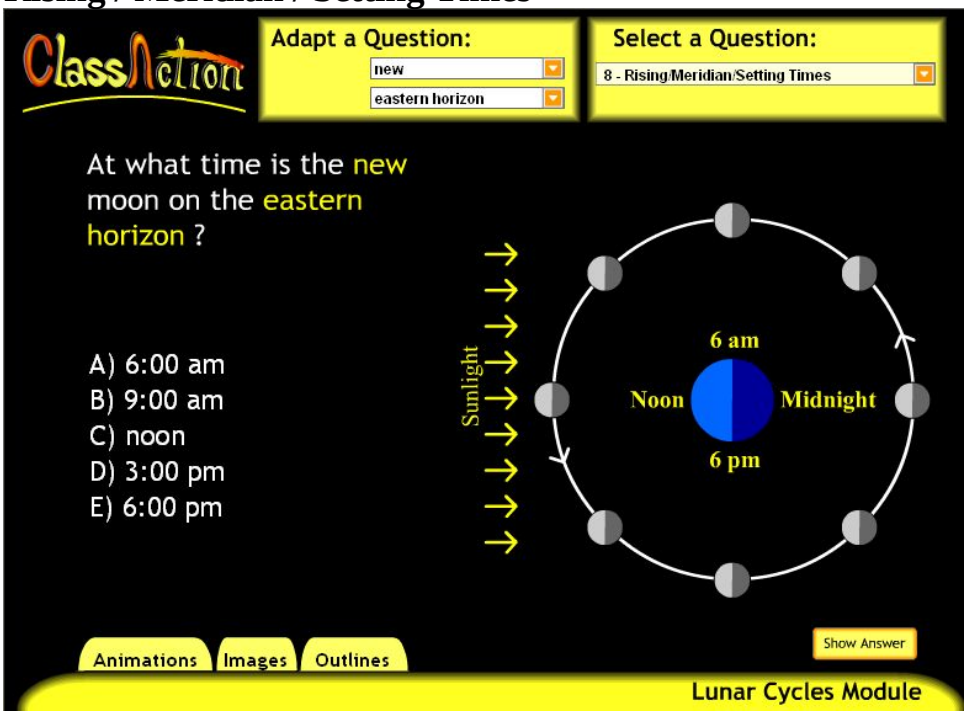
Phase interval 1 (1st quarter to a slight waning gibbous) is about 10 days.
Phase interval 2 (waning gibbous to waning crescent) is about 7 days.
Phase interval 3 (waxing crescent to 3rd quarter) is about 18 days.
Phase interval 4 (full moon to waning gibbous) is about 4 days.
Phase interval 5 (waning crescent to waxing gibbous) is about 14 days.

Suggestions:
There are 5 different adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Lunar Phases Simulator.

Difficulty: 3

Rising / Meridian / Setting Times



Key Concept: Phases of the Moon

Secondary Concepts: Causes for Phases of the Moon; Meridian

Description:
The image above displays the Earth, the Moon at eight different possible locations in its orbit around the Earth, the incident direction of sunlight, and the approximate time of day for different locations on the Earth. Students should determine at what time of day a selected phase of the moon will occur for a selected local horizon system location.

Answer:
The Moon will always rise on the eastern horizon, set on the western horizon, and be directly overhead when on the meridian; thus:

The new moon is on the eastern horizon / meridian / western horizon at 6 am / Noon / 6 pm.
The waxing crescent moon is on the eastern horizon / meridian / western horizon at 9 am / 3 pm / 9 pm.
The first quarter moon is on the eastern horizon / meridian / western horizon at Noon / 6 pm / Midnight.
The waxing gibbous moon is on the eastern horizon / meridian / western horizon at 3 pm / 9 pm / 3 am.
The full moon is on the eastern horizon / meridian / western horizon at 6 pm / Midnight / 6 am.
The waning gibbous moon is on the eastern horizon / meridian / western horizon at 9 pm / 3 am / 9 am.
The 3rd quarter moon is on the eastern horizon / meridian / western horizon at Midnight / 6 am / Noon.

The waning crescent is on the eastern horizon / meridian / western horizon at 3 am / 9 am / 3 pm.

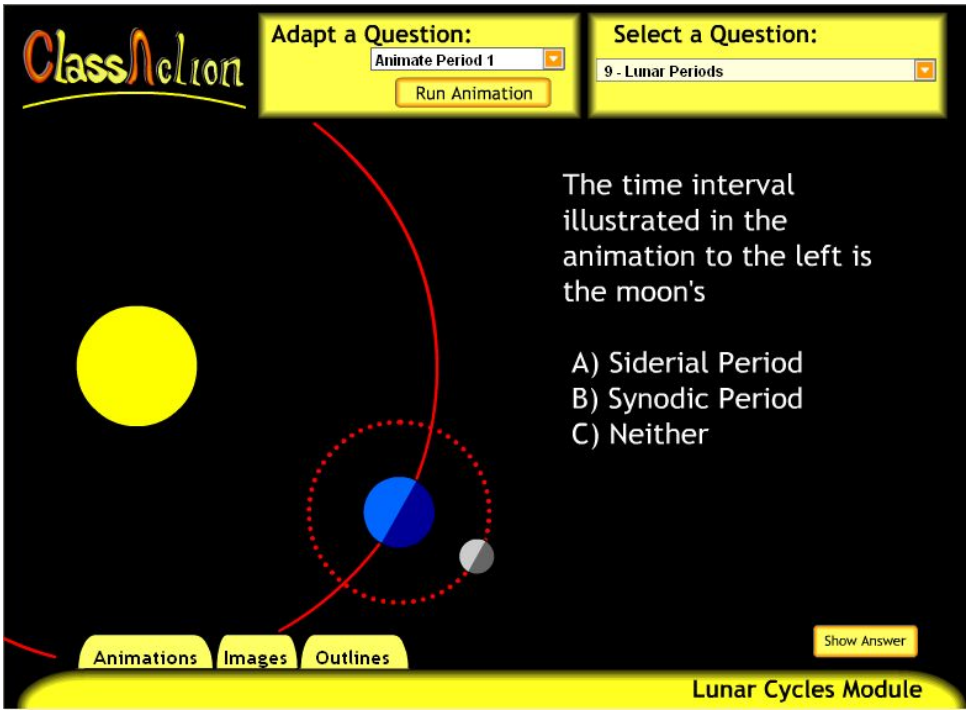
Suggestions:
There are 24 different adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Lunar Phases Simulator.

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Difficulty: 3

Lunar Periods



Key Concept: Synodic and Sidereal periods

Secondary Concepts: Causes for Phases of the Moon

Description:
An image above displays the Sun, the Earth and its orbital path (solid red line), and the Moon and its orbital path (dotted red line). As the animation proceeds, the Earth will orbit the Sun while the Moon orbits the Earth for a certain period of time. Students should determine whether the period depicted is a lunar sidereal period, a lunar synodic period, or neither.

Answer:
A lunar synodic period is defined as the amount of time between successive similar lunar phases (for example, from full moon to full moon). The lunar sidereal period is defined as the amount of time it takes for the Moon to revolve around the Earth, as measured with respect to the stars. Thus:

Animate Period 1 corresponds to a synodic period.
Animate Period 2 corresponds to a sidereal period.
Animate Period 3 corresponds to neither (it actually is one-half of a synodic period).

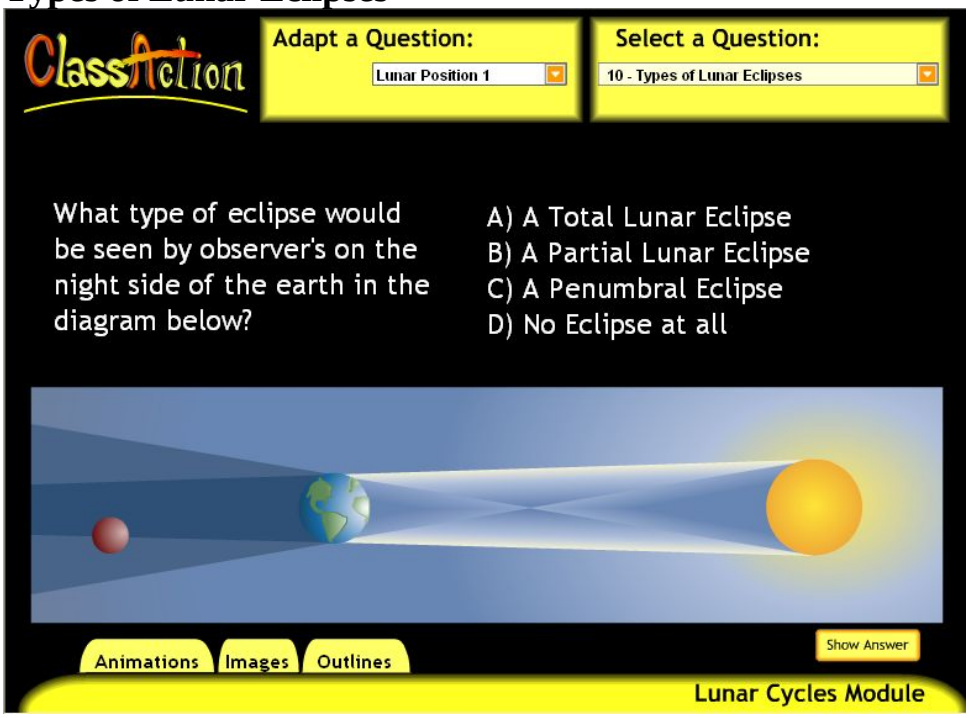
Suggestions:
There are 3 different adaptations to the question, therefore the instructor could talk through and present the solutions to one adaptation and use the think-pair-share method with the remaining adaptations.

Recommended images: Lunar Sidereal Period; Lunar Synodic Period.

Recommended outlines: Lunar Periods.

Difficulty: 3

Types of Lunar Eclipses



Key Concept: Eclipse

Secondary Concepts: Umbra and Penumbra

Description:
The image above displays the Sun, the Earth, and the Moon. The configuration corresponds to a specific type of lunar eclipse based upon the lunar position selected. Students should determine which type of lunar eclipse is displayed.

Answer:
The darkest part of the shadow cast by the Earth is the umbra and the lesser dark part is the penumbra. When the Moon passes completely into the umbra, it is a total lunar eclipse. When the Moon passes only partially into the umbra, it is a partial lunar eclipse. When the Moon only passes through the penumbra, it is a penumbral eclipse. Thus:

Lunar position 1 is a partial lunar eclipse.
Lunar position 2 is a no eclipse at all.
Lunar position 3 is a penumbral lunar eclipse.
Lunar position 4 is a total lunar eclipse.

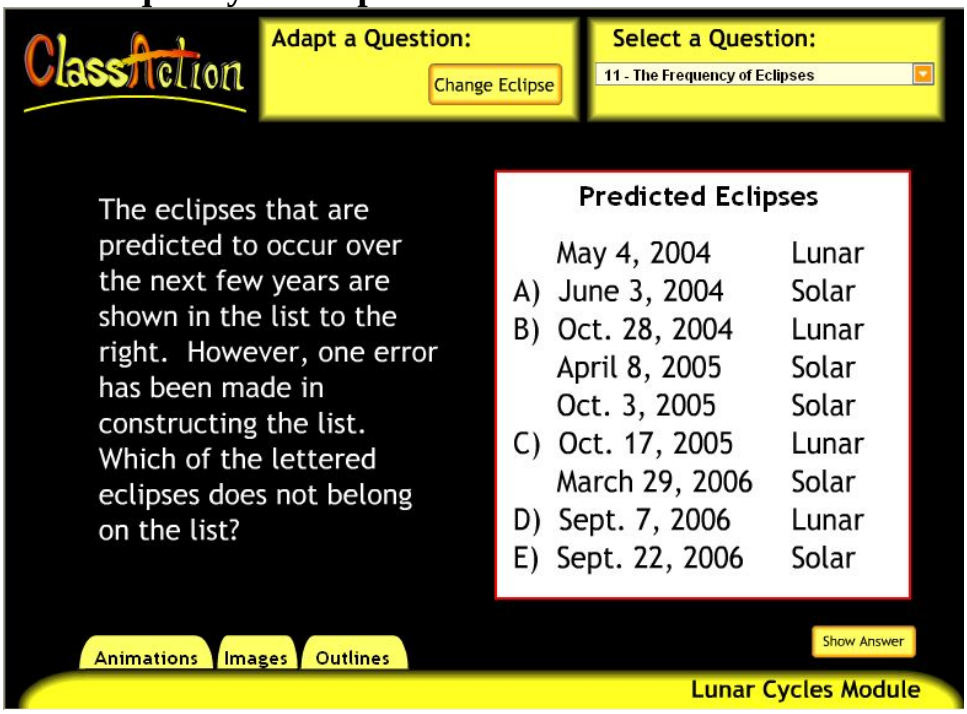
Suggestions:
There are 4 different adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended images: Types of Shadow; Lunar Eclipse I; Lunar Eclipse II

Recommended outlines: Lunar Eclipses

Difficulty: 2

The Frequency of Eclipses



Key Concepts: Eclipse Seasons

Secondary Concepts: Eclipses

Description:
A question is presented that provides a table of predicted eclipses over the next couple of years. However, one eclipse prediction has been made in error. Students should determine which eclipse prediction is the erroneous one.

Answer:
The Moon's orbit is tilted at about a 5^{o} angle with respect to the ecliptic plane of the Sun and Earth. As a result, the Moon intersects the ecliptic plane only twice for any given orbit around the Earth. Eclipses can only occur during "eclipse seasons," when the Moon happens to be at or near a node during a new or full moon phase. Only then will the shadows of the Earth or Moon actually interact with the other. Eclipse seasons separated by slightly less than 6 months, so the dates between two successive lunar or solar eclipses should be about 6 months apart.

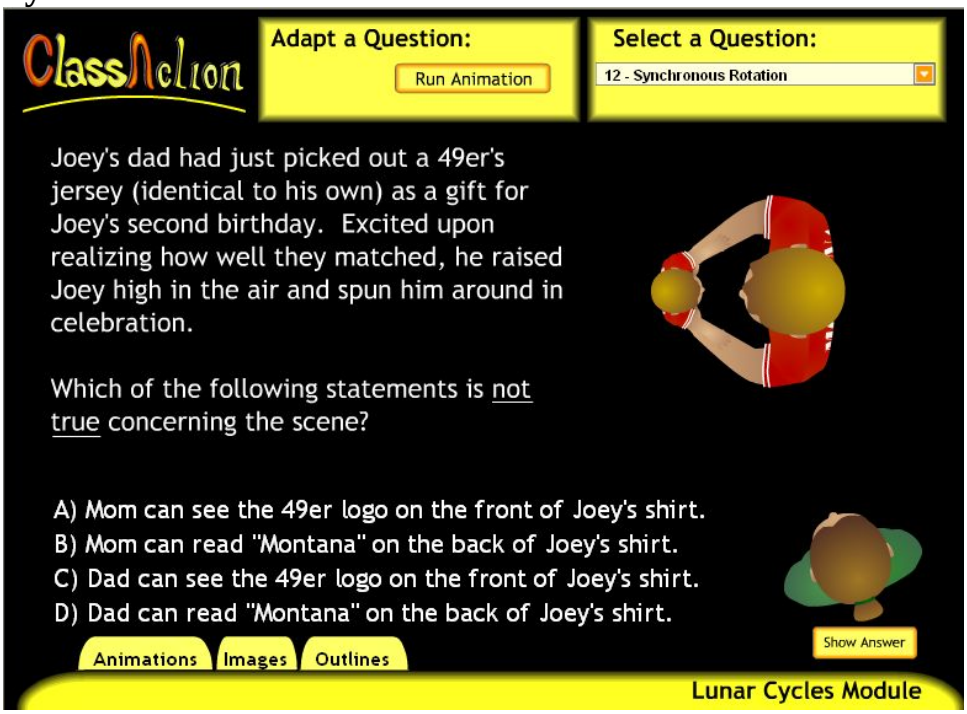
Suggestions:
There are numerous adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Eclipse Table

Recommended images: Line of Nodes; Eclipse Seasons

Difficulty: 3

Synchronous Rotation



Key Concept: Synchronous rotation

Description:
The image above displays a top view of a child being held by his father while the mother looks on. As the animation proceeds, the father begins to rotate counterclockwise with child in arms. Students should determine which statement is incorrect in regards to the scene.

Answer:
Synchronous motion occurs when one side of an object in rotational motion always faces another object. As the father and son rotate, their motion can be described as being "synchronous with each other" as they are both always facing each other. Thus:

The statement "Dad can read "Montana" on the back of Joey's shirt" is not true.

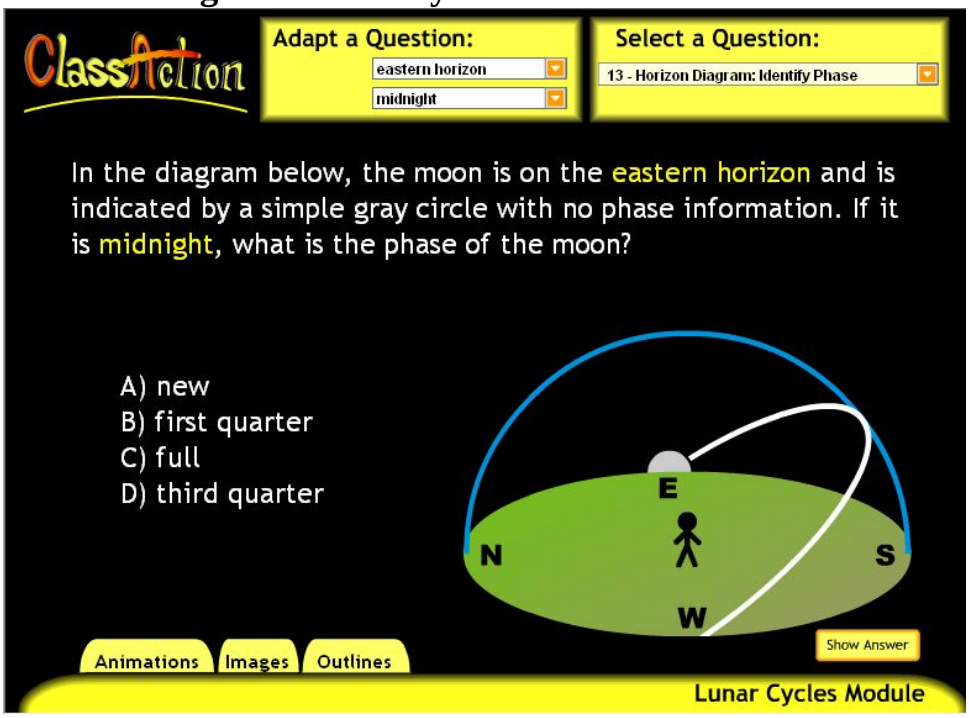
Suggestions:
Recommended animations: 3 Views Simulator.

Hints:
Perhaps ask if the father thinks that Joey is rotating, which can only occur if the father sees all sides of Joey.

Also, perhaps ask if the mother thinks Joey is rotating.

Difficulty: 2

Horizon Diagram – Identify Phase



Key Concept: Causes for Phases of the Moon

Secondary Concepts: Phases of the Moon; Local Horizon system; Meridian

Description:
The image above displays a local horizon system with the Moon at a selected location in the sky at a selected time. Also shown is the apparent path of the Moon through the local horizon system. Students should determine which lunar phase corresponds with the information selected.

Answer:
To be on the eastern horizon means that the Moon is rising, to be on the western horizon it is setting, and to be on the meridian means it is highest in the sky. By using an image similar to the one used for the Rising / Meridian / Setting question, one can determine when certain phases will rise, set, or be located on the meridian. Thus:

On the eastern horizon at Midnight / 3 am / 6 am / 9 am / Noon / 3 pm / 6 pm / 9 pm, the Moon with be at a 1st quarter / waxing gibbous / full / waning gibbous / 3rd quarter / waning crescent / new moon / waxing crescent phase.

On the meridian at Midnight / 3 am / 6 am / 9 am / Noon / 3 pm / 6 pm / 9 pm, the Moon with be at full / waning gibbous / 3rd quarter / waning crescent / new moon / waxing crescent phase / 1st quarter / waxing gibbous.

On the western horizon at Midnight / 3 am / 6 am / 9 am / Noon / 3 pm / 6 pm / 9 pm, the Moon with be at a 3rd quarter / waning crescent / new moon / waxing crescent phase / 1st quarter / waxing gibbous / full / waning gibbous.

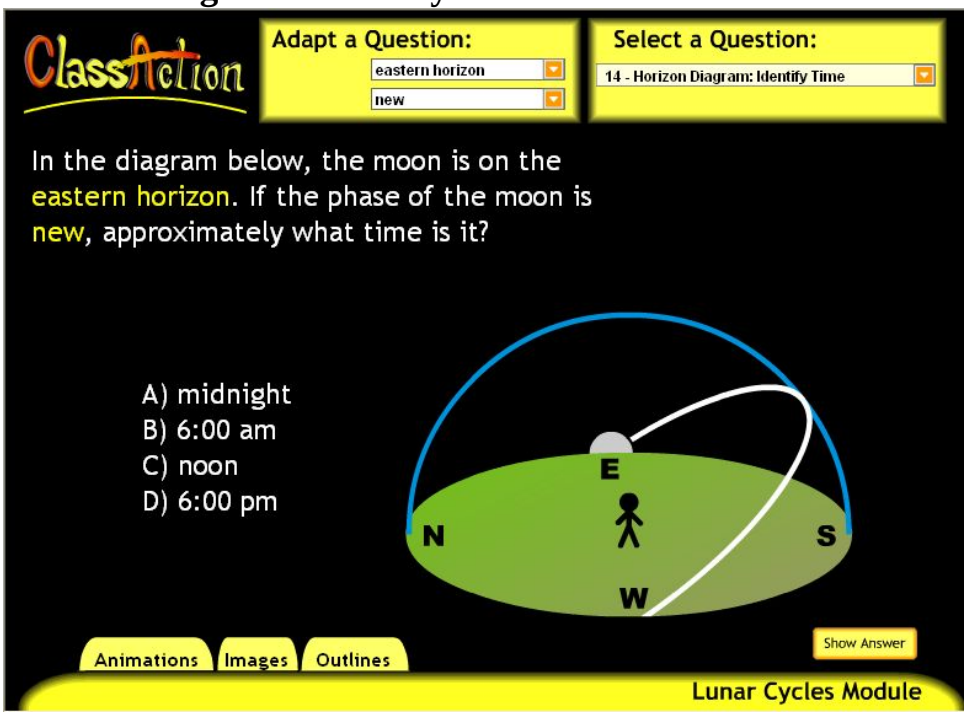
Suggestions:
There are 24 adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Lunar Phases Simulator.

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Difficulty: 3

Horizon Diagram – Identify Time



Key Concept: Causes for Phases of the Moon

Secondary Concepts: Phases of the Moon; Local Horizon system; Meridian

Description:
The image above displays a local horizon system with the Moon at a selected location in the sky at a selected time. Also shown is the apparent path of the Moon through the local horizon system. Students should determine which time of day corresponds with the information selected.

Answer:
To be on the eastern horizon means that the Moon is rising, to be on the western horizon it is setting, and to be on the meridian means it is highest in the sky. By using an image similar to the one used for the Rising / Meridian / Setting question, one can determine when certain phases will rise, set, or be located on the meridian. Thus:

On the eastern horizon at Midnight / 3 am / 6 am / 9 am / Noon / 3 pm / 6 pm / 9 pm, the Moon with be at a 1st quarter / waxing gibbous / full / waning gibbous / 3rd quarter / waning crescent / new moon / waxing crescent phase.

On the meridian at Midnight / 3 am / 6 am / 9 am / Noon / 3 pm / 6 pm / 9 pm, the Moon with be at full / waning gibbous / 3rd quarter / waning crescent / new moon / waxing crescent phase / 1st quarter / waxing gibbous.

On the western horizon at Midnight / 3 am / 6 am / 9 am / Noon / 3 pm / 6 pm / 9 pm, the Moon with be at a 3rd quarter / waning crescent / new moon / waxing crescent phase / 1st quarter / waxing gibbous / full / waning gibbous.

Suggestions:
There are 24 adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Lunar Phases Simulator.

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Difficulty: 3

Section 3: *Challenge Questions*

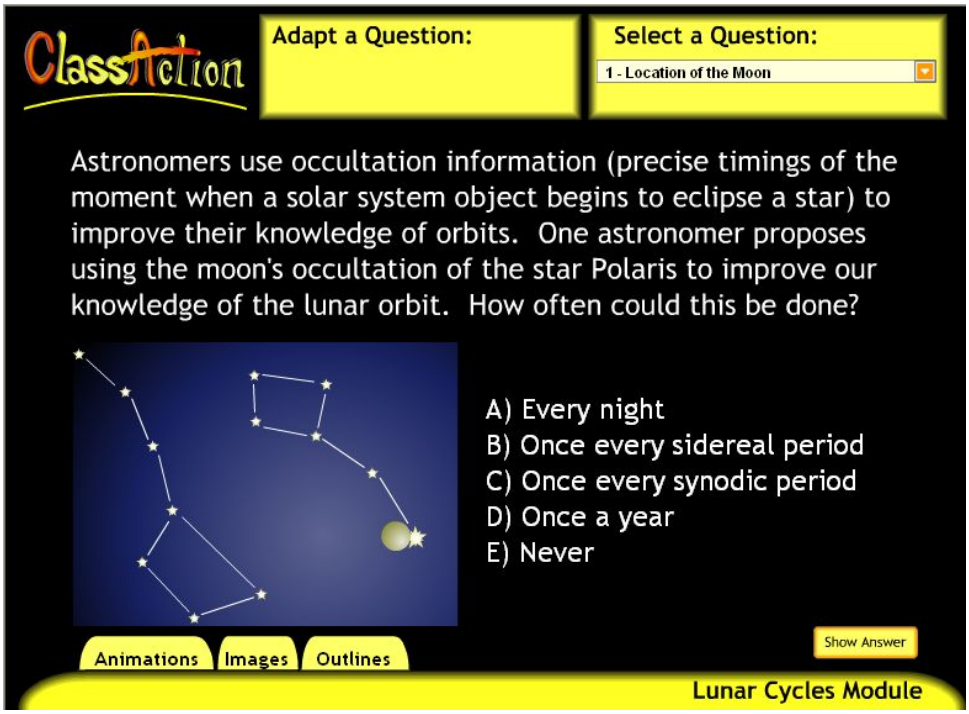
This section contains astronomy questions that are designed to be more challenging to the students. These questions are not only designed to test 2 – 4 astronomical concepts, but students must synthesize these concepts in a context that they would not have been generally covered in a lecture and/or textbook.

It is recommended that the think-pair-share method be employed for these questions.

Teaching suggestions, and possibly hints, are provided for every question.

A degree of difficulty (1 – 5; 1 being easy and 5 being difficult) is also provided for every question.

Location of the Moon



Key Concept: Orbit of the Moon

Secondary Concepts: Declination; Ecliptic

Description:
The image above displays the Moon near the star Polaris. Students should determine how often the Moon would actually occult Polaris.

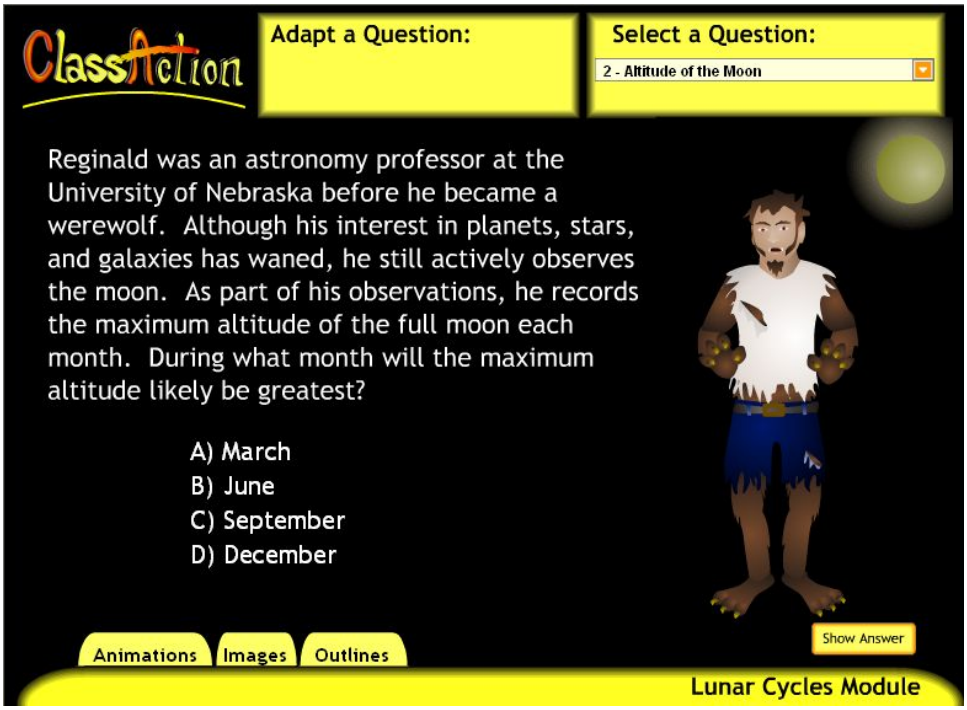
Answer:
The Moon orbits the Earth at a 5^o tilt to the ecliptic plane, which means that the Moon can only exist in the sky within a $\pm 5^o$ range of the ecliptic. The ecliptic, in turn, is always within a $\pm 23.5^o$ range of the celestial equator. This means the Moon can only have possible declination values that are within $\pm 28.5^o$. Thus:

The Moon will never occult Polaris, which has a declination of $+90^o$.

Suggestions:
Recommended animations: Moon Inclination Simulator

Difficulty: 3

Altitude of the Moon



Key Concept: Causes for Phases of the Moon

Secondary Concepts: Declination; Ecliptic; Solstice and Equinox

Description:
A question is presented that indicates that the full moon will most likely be highest in the sky during a given month of the year. Students should determine which month that would be.

Answer:
This question is implied to take place in the northern hemisphere, presumably near Lincoln, Nebraska. When a full moon occurs, this means that the Sun and the Moon are on opposite sides of the celestial sphere (and space for that matter). Therefore, the Moon would most likely be highest in the sky when the Sun is most likely lowest in the sky, which is at the winter solstice. Thus:

The Moon will most likely have a maximum altitude (highest in the sky) in December – the month of the winter solstice.

Suggestions:
Recommended animations: Lunar Phases Simulator.

Hints:
Perhaps ask the students when the Sun appears to have its highest and lowest altitude in the sky during the year and then tie the geometric orientation of the full moon phase.

Difficulty: 3

Earthrise on the Moon

Key Concept: Causes for the Phases of the Moon

Secondary Concepts: Phases of the Moon

Description:
The Apollo 11 photograph above displays a gibbous Earth as seen from the Moon. Students should determine the phase of the Moon as seen from Earth at the time of the photograph.

Answer:
Consider the following: if it was a full moon as seen from Earth, then an astronaut looking back at the Earth would see an Earth in shadow – a new Earth. If it was a new moon as seen from Earth, then an astronaut looking back at the Earth would see an Earth fully lit up – a full Earth. This logic can be extended to all the other possible pair of phases; whatever phase one has, the other has the opposite. Thus:

The Moon must be in a crescent phase.

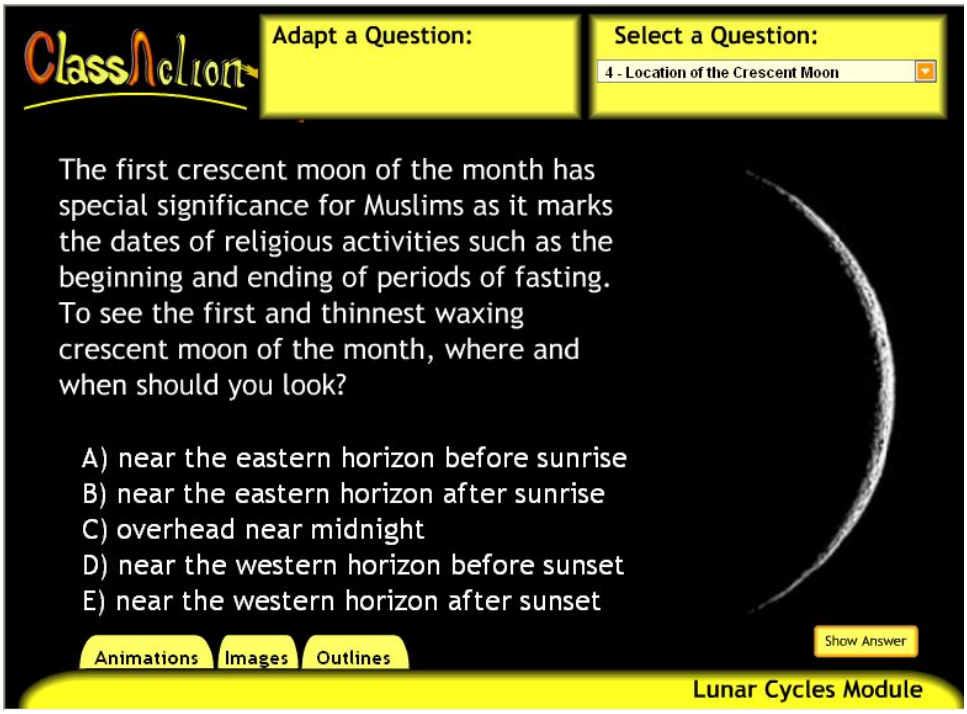
Suggestions:
Have the students draw a simple sketch of the Sun and Earth. For the Earth, have the students shade in the side of the Earth not illuminated by the Sun. Then ask the students where the Moon would have to be in order to see the phase of Earth in the photograph. Students may have to be reminded that the Apollo 11 landing was near the equator of the Moon.

Recommended animations: 3 Views Simulator

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Difficulty: 3

Location of the Crescent Moon



Key Concept: Causes for the Phases of the Moon

Secondary Concepts: Phases of the Moon

Description:
A question is presented that a very thin waxing crescent is desired to be seen. Students should determine at what time of day and in what local direction should they look to see this phase.

Answer:
Just prior to the very thin waxing crescent is the new moon, which rises at sunrise. Over the course of a day, the phase of the Moon does not change much, but it does change slightly. This means that by the end of the day the new moon will have changed to a very thin waxing crescent. Thus:

The very thin waxing crescent will be near the western horizon before sunset.

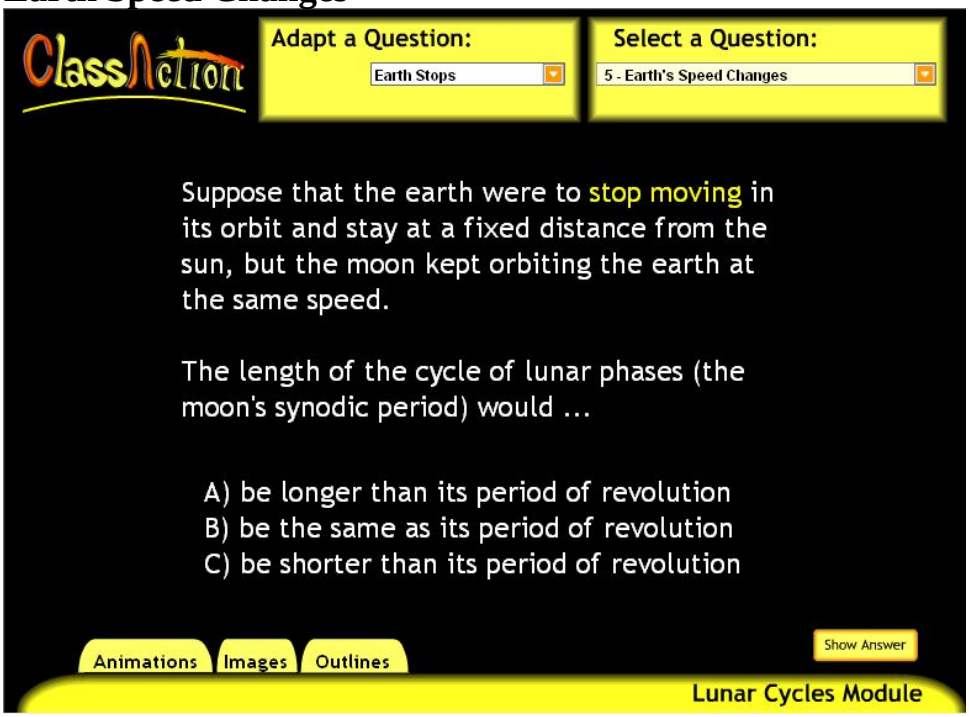
Suggestions:
Have the students identify the phase of the Moon just prior to the very thin waxing crescent (new moon) as draw a simple sketch. Then perhaps ask if over the course of the day will a lunar phase change. This allows them to hopefully integrate the rate at which the Moon orbits the Earth with the transition of phases.

Recommended animations: 3 Views Simulator; Lunar Phases Simulator

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images.

Difficulty: 4

Earth Speed Changes



Key Concept: Synodic Period; Sidereal Period

Description:
An incomplete sentence is presented that indicates that the rate of the Earth's revolution has changed. Students should determine how the synodic period of the Moon would change when compared to its sidereal period because of the Earth's change.

Answer:
The sidereal period is the period of revolution around the Earth. As long as the mass of Earth, the speed of the Moon, and the distance from the Earth and Moon are unchanged, so will the sidereal period. The sidereal period of the Moon does not depend upon the revolution speed of the Earth. The synodic period of the Moon is the time interval from one phase cycle to the next, which essentially corresponds to the time from one Sun-Earth-Moon configuration to the next similar configuration. As long as the Earth revolves, the Moon will make a complete revolution and then have to travel along its orbit a bit longer to "catch up" with the Earth to create a similar Earth-Sun-Moon. This means that as long as the Earth revolves in the same direction of the Moon, the synodic period will be longer than the sidereal period. Thus:

If the Earth were to stop revolving, the synodic period would equal the sidereal period.
If the Earth's revolution were to slow down or speed up, as long as it was still revolving in the same direction as the Moon's revolution, the synodic period would be longer than the sidereal period.

Suggestions:
There are 3 adaptations to the question, therefore the instructor could talk through and present the solutions to one adaptation and use the think-pair-share method with the remaining adaptations.

Recommended images: Lunar Sidereal Period; Lunar Synodic Period

Recommended outlines: Lunar Periods.

Difficulty: 4

Section 4: *Discussion Questions*

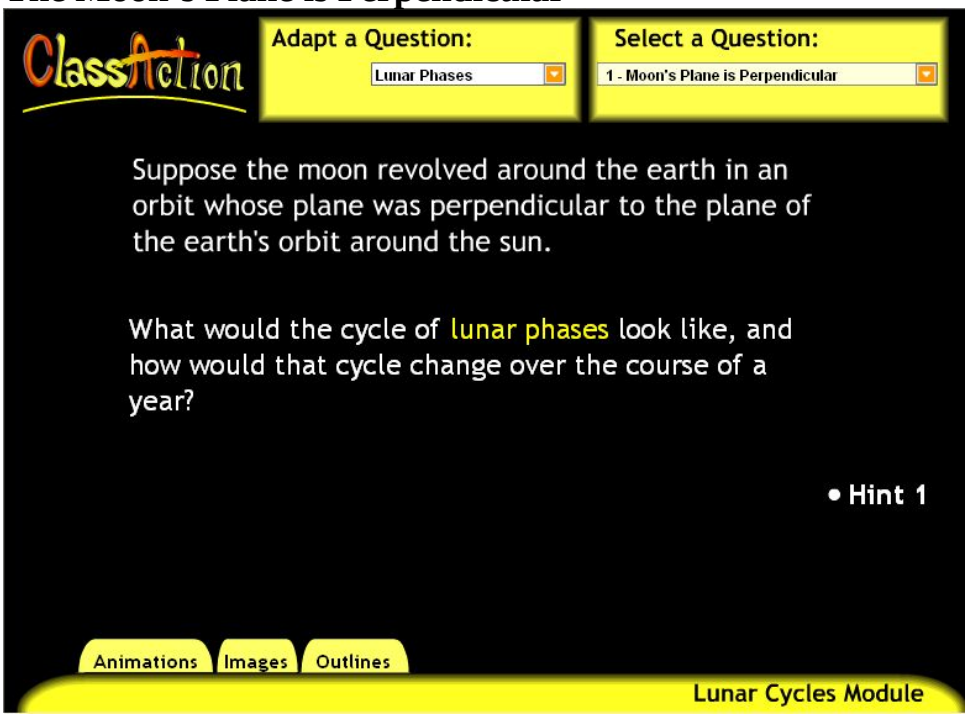
This section contains discussion questions. These questions do not have answer options since they are sufficiently complicated to require a few sentences to a paragraph to answer.

It is recommended that the students discuss these questions in groups and then make oral reports to the class of their conclusions.

Teaching suggestions, and possibly hints, are provided for every question.

A degree of difficulty (1 – 5; 1 being easy and 5 being difficult) is also provided for every question.

The Moon's Plane is Perpendicular



Key Concept: Causes of the Phases of the Moon

Secondary Concepts: Phases of the Moon

Description:
A question is presented that imagines the Moon's orbit of revolution to be perpendicular to the ecliptic plane of the Earth and Sun. Students should determine how this would change the appearance of the lunar phases and the possibilities of eclipses over the course of the year.

Answer:
The monthly cycle of the phases would be very similar to our present cycle during the months of the year when the plane of the Moon's orbit is parallel to the direction of the Sun's rays. However, the Moon would be traveling through space more perpendicular to the celestial equator than parallel (as it is now) and the terminator on the Moon would be aligned east-west instead of the north-south.

During the months when the plane is perpendicular to the Sun's rays, the Moon would be in a constant quarter phase. The transition months in-between these two extremes are complicated.

There would still be two eclipse seasons corresponding to when the plane of the Moon's orbit is parallel with the Sun's ray. However, eclipses would be far more infrequent.

Suggestions:
Recommended animations: Moon Inclination Simulator.

Recommended images: Lunar Phases – Drawing; Lunar Phases – Images; Eclipse Seasons.

Hints:
This question provides a hint in the form of an image depicting a perpendicular lunar orbit at 4 locations of the Earth in its orbit around the Sun.

Difficulty: 5

Phases from the North Pole

Key Concepts: Causes for the Phases of the Moon

Secondary Concepts: Celestial sphere; Solstice and Equinox; Ecliptic

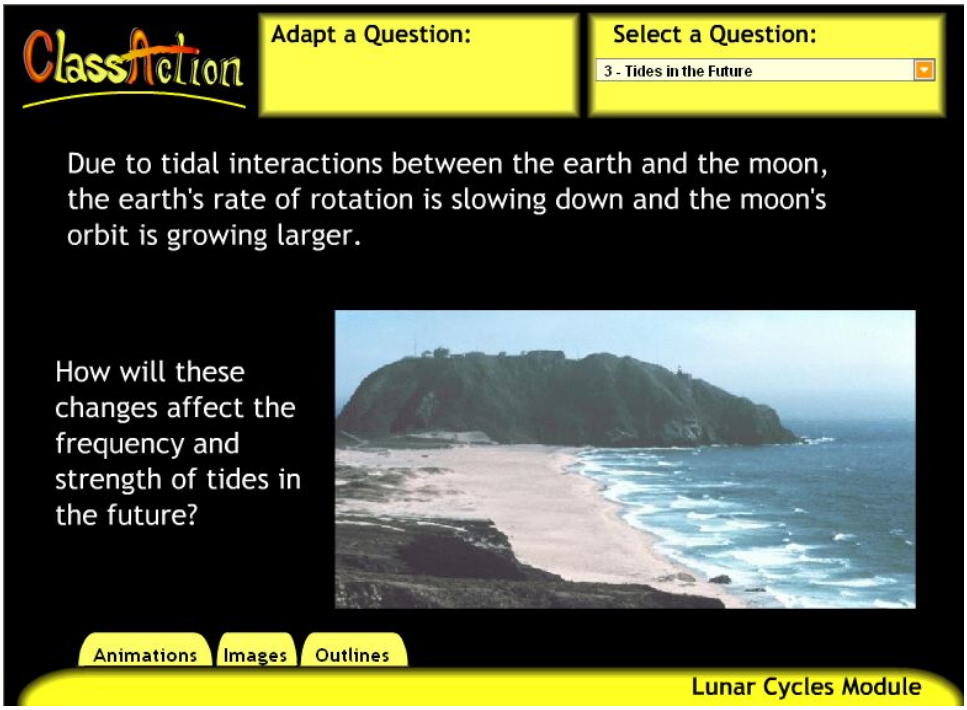
Description:
The image above displays a scene involving Santa's Toy shop, which implies a location at the North Pole of the Earth. Also shown is a full moon rising on the horizon. Students should determine approximately how many days are left until late December.

Answer:
For the Moon to be full, the Sun and the Moon must be opposite each other in the sky. Since the full moon is rising, the Sun must be setting. The only day of the year the Sun sets at the North Pole is during the autumnal equinox, after which it will stay set for about 6 months. If the autumnal equinox is Sept. 21st, and Christmas eve is Dec. 24th, that's about 95 days. (However, this assumes that the moon is on the ecliptic. Due to the inclination of the moon's orbit relative to the ecliptic, this answer can be off by a couple of weeks.)

Hints:
This question provides 3 hints that lead the students toward a picture of the local horizon for a location at the North Pole. Then the students should properly place the rising Moon and setting Sun onto the picture in order to produce a full moon.

Difficulty: 5

Tides of the Future



Key Concept: Causes of the Tides

Description:
A question is presented that indicates that the Earth is slowing down and the Moon is moving farther away. Students should determine how these changes will affect the frequency and strength of the tides in the future.

Answer:
The strength of the tides depends upon the magnitude of the differential force across the diameter of the Earth due to the Moon's gravitational force on the Earth. As the Moon moves farther away, this differential force will decrease until essentially there will be no differential force affecting the Earth and therefore no tides.

As the rotation of the Earth decreases, the time it takes for a given location on the Earth to rotate "into" a tidal bulge will increase or conversely the frequency of tides will decrease.

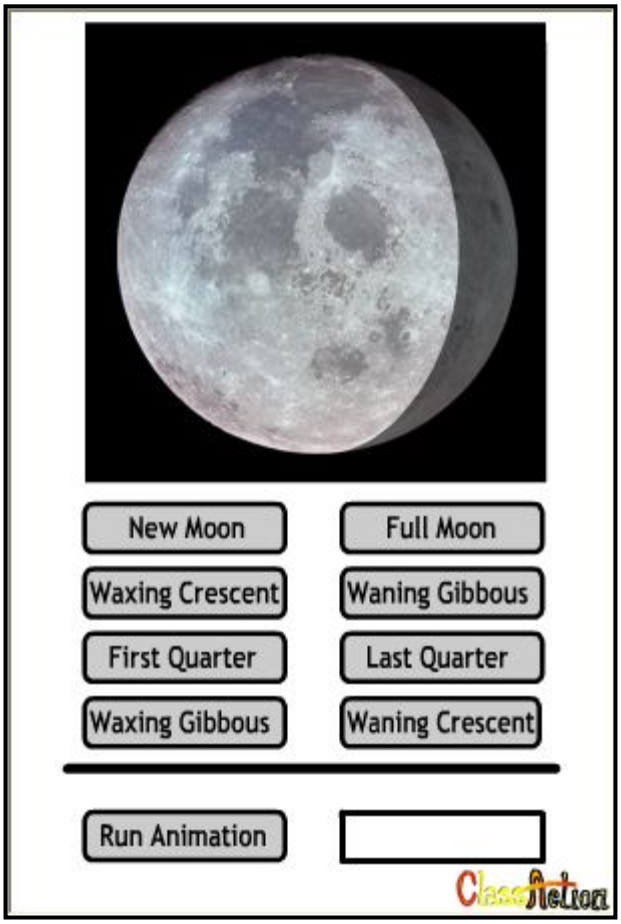
Suggestions:
Recommended animations: Tidal Bulge Simulator.

Difficulty: 3

Section 5: *Animation Resources*

This section contains a basic primer for each of the animation resources provided for this module. The intent of each animation resource is to supplement and support the discussions generated by the questions presented in this module, which in turn will hopefully lead to a better understanding of the astronomical topics and concepts involved.

Lunar Phase Vocabulary



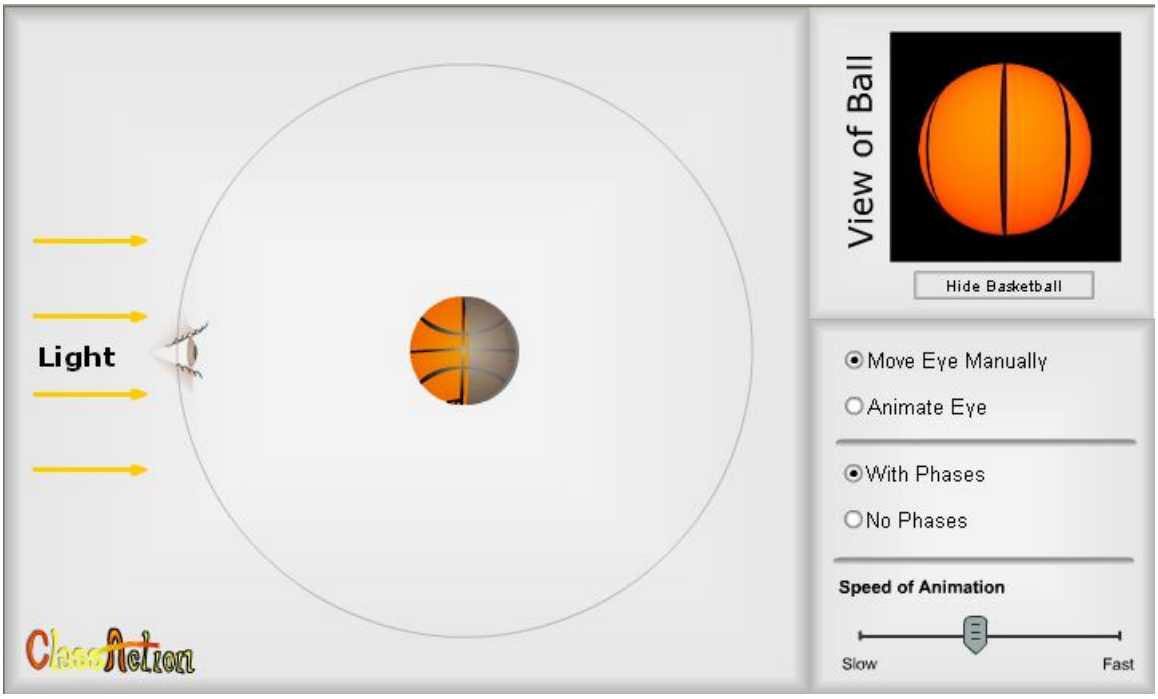
Main Purpose:
This simulator allows the user to view the eight named phases of the Moon.

Images:
The image displays a photograph of the Moon at a selected a lunar phase.

Controls:
When a specific lunar phase is selected, the picture changes accordingly.

The user can also click the "Run/Stop Animation" button to view the picture of the Moon slowly going through the entire lunar phase cycle. The time in days that have passed since the phase of the moon that was being displayed when the button was clicked is shown at the bottom right. The user can click the "Run/Stop Animation" at any time. If "Run/Stop Animation" button is subsequently clicked, the timer will reset to zero.

Basketball Phases Simulator



Main Purpose:
This simulator allows the user to observe the view the basketball from various points of view around it, and allows the user to view various phases of the basketball when the light is turned on. This simulator should be used to help better understand the lunar phase cycle.

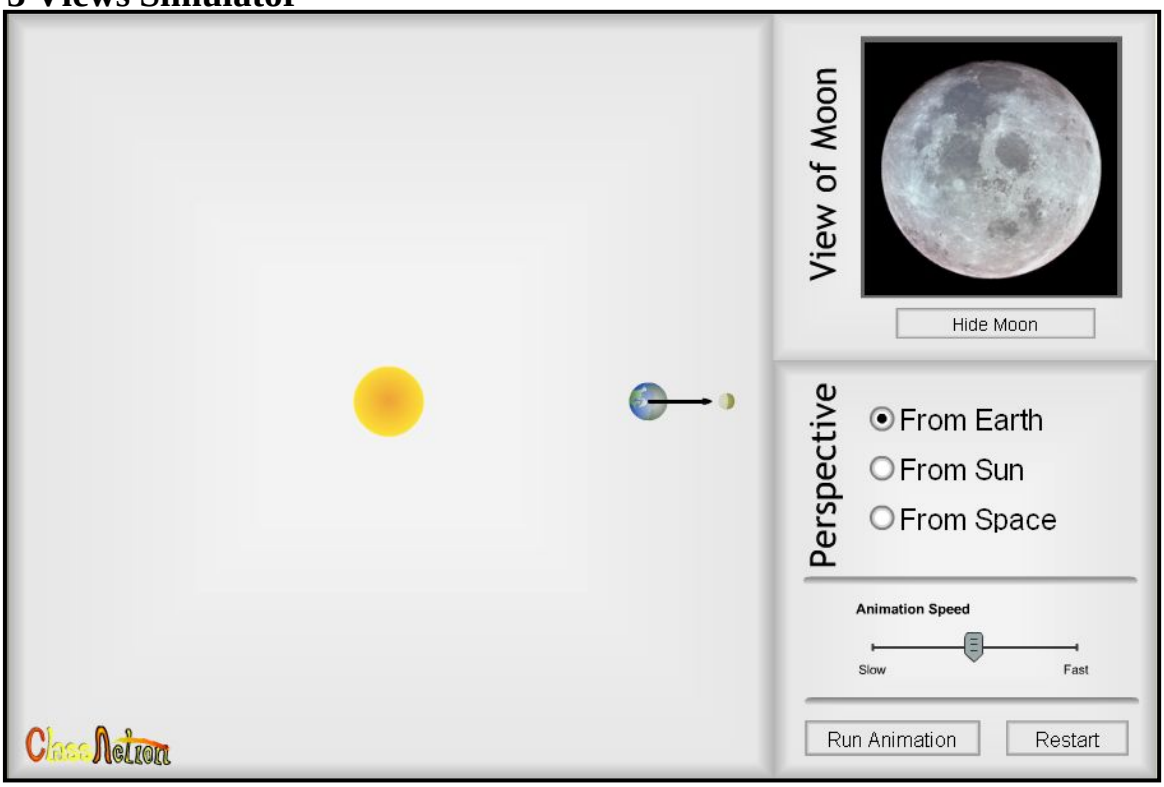
Image:
The image displays an eye that represents a point of view for a motionless basketball at the center. A light is shown to be off the screen to the left. In the upper right, a view of the basketball as the eye would see it is shown (View of Ball).

Controls:
At the middle right, the user can choose to move the eye manually by clicking the "Move Eye Manually" button and then clicking and dragging the eye to any point around the basketball. The user can also allow the eye to rotate around the basketball by itself by clicking the "Animate Eye" button. The speed of the rotation can be controlled at the bottom right. In either case, the View of Ball image will change accordingly.

The user can also choose to turn off the light by clicking "No Phases," or turn on the light by clicking "With Phases."

For prediction purposes, the basketball can be hid in the View of Ball image by clicking the "Hide/Show Basketball" button.

3 Views Simulator



Main Purpose:
This simulator allows the user to observe, from multiple points of view, any observational changes of the Moon that may occur as the Earth and Moon revolve.

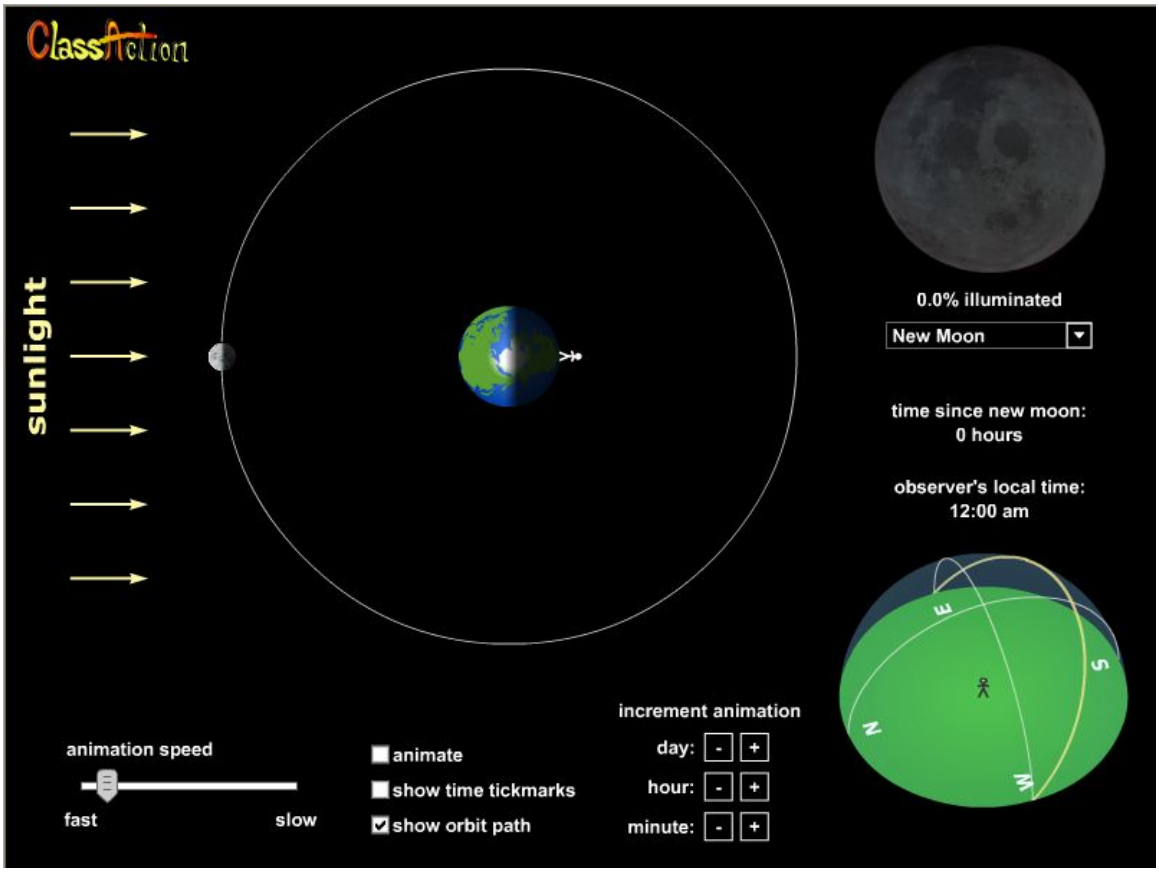
Image:
The image displays the yellow Sun at the center, a blue Earth, and a gray Moon. The arrow represents the current point of view (as shown: as seen from Earth). In the upper right, a view of the Moon from the selected point of view is shown (View of Moon).

Controls:
At the middle right, the user can choose which perspective, or point of view, they wish to investigate by clicking the appropriate perspective button. By clicking the "Run/Stop Animation" button at the lower right, the Earth will begin to revolve around the Sun and the Moon around the Earth. The View of Moon image will change accordingly. The speed of the animated motions can also be controlled at the bottom right.

For prediction purposes, the Moon can be hid in the View of Moon image by clicking the "Hide/Show Moon" button.

At any time the user can restart the simulator by clicking "Restart" at the bottom right.

Lunar Phases Simulator



Main Purpose:
This simulator allows the user to investigate the revolution of the Moon around the Earth, the subsequent phases of the Moon, and the motion of the Moon in a northern latitude horizon system.

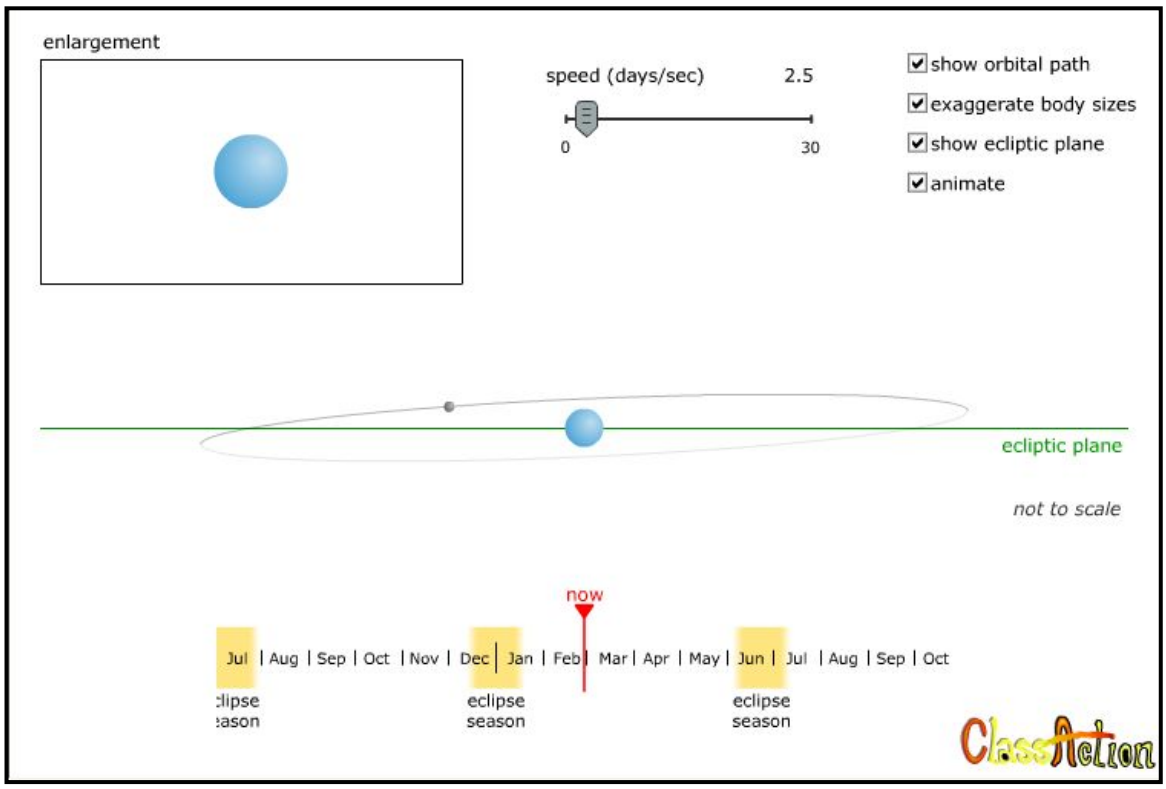
Images:
At the center is an image of the Earth, the Moon's orbit, and the Moon. Sunlight shines from a distant Sun off to the left which illuminates the left side of the Earth and Moon. On the Earth a small figure represents an observer in the northern hemisphere. At the upper right is an image of the Moon as seen from the Earth, which is equivalent to the phase of the Moon. In the lower right is a northern latitude horizon system for the same observer depicted on the spherical Earth. The yellow line is the ecliptic where any motion of the Sun and the Moon will take place (the 5^{o} tilt of the Moon's orbit is ignored for this simulation).

Controls:
There are multiple ways the user can manipulate the images in order to better investigate the phenomena involved. To move the Moon along in its orbit around the Earth, the Moon can be clicked and dragged to any location in its orbit, or it can be incremented by day, hour, or minute at the lower right. To rotate the Earth to a specific time of day, the Earth can also be clicked and dragged. Both the motion of the Moon and the Earth can

proceed simultaneously in a simulated "normal" fashion by clicking the "animate" button at the middle bottom. The speed of the motions can be controlled at the bottom left. As any of these changes are made, the View of Moon image and the local horizon change accordingly (including small images of the Moon and Sun as they travel across the local horizon sky).

At the middle bottom, the user can also choose to show or not show the time tick marks and orbital path of the Moon.

Moon Inclination Simulator



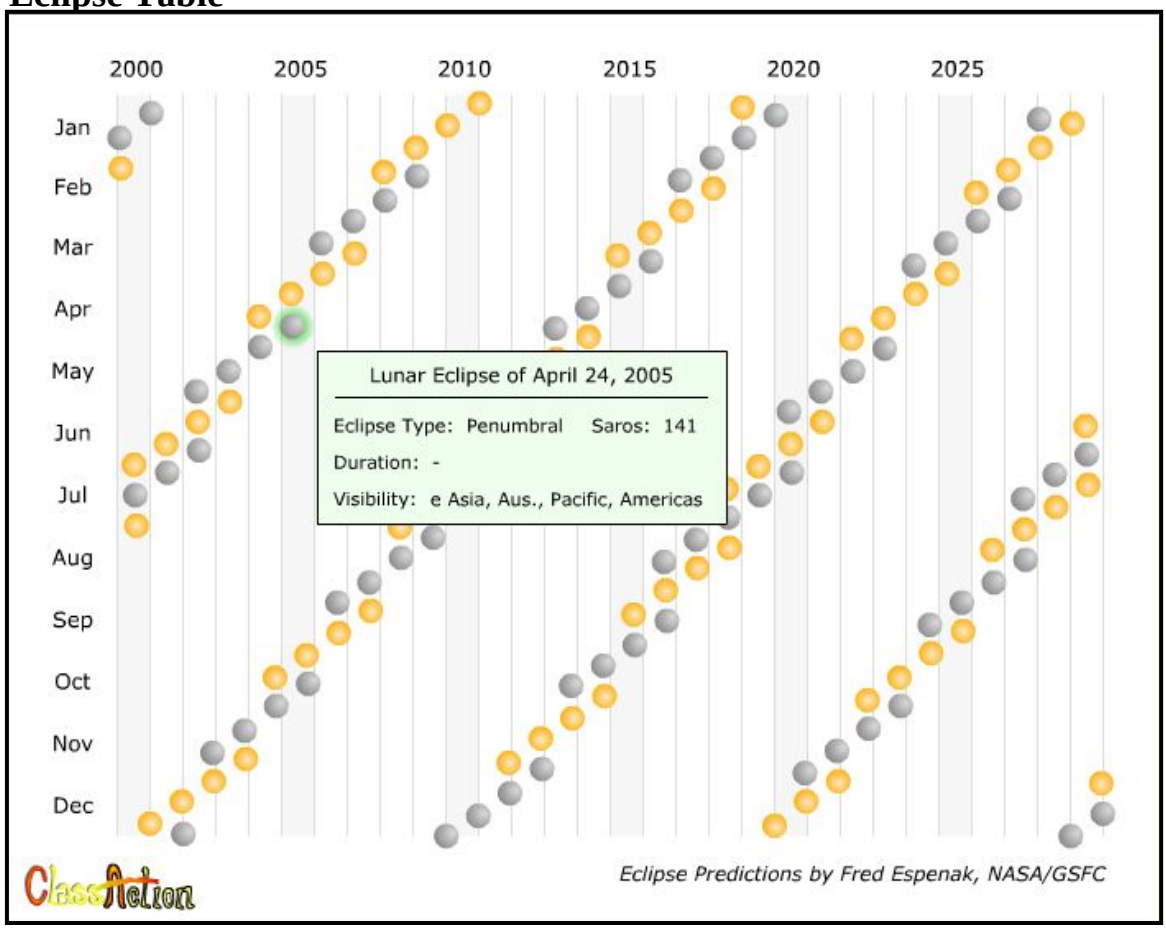
Main Purpose:
This simulator allows the user to view and investigate the cause and frequency of eclipses. A secondary purpose is to illustrate the correct relative scale of the Earth, moon, and the lunar orbit – The moon is ¼ the size of the Earth and its orbit is 30 times the size of the Earth.

Image:
The main image displays a cross-sectional view of a blue Earth on the ecliptic plane. Around the Earth is the tilted orbital path and small image of the Moon. At the upper left is an enlarged image of the Earth so that when the Moon passes in front of or behind the Earth this can be view easier. At the bottom is an indication of which day of the year it is meant to be and the time intervals of when the Moon is near or crosses the ecliptic plane (eclipse seasons).

Controls:
At the upper right, the user can start and stop the simulated motion by clicking the "animate" button. The speed of the motion can be controlled at the upper middle.

The user can also show or not show the ecliptic plane and orbital path of the Moon, as well as the size of the Earth and Moon, at the upper right.

Eclipse Table



Main Purpose:
This simulator allows the user to view and gain information about past, present, and future lunar and solar eclipses.

Image:
The image displays a grid of month vs. calendar year. The small gray and yellow circles represent a specific lunar or solar eclipse (respectively) that will occur during the month and year where it is located on the grid.

Controls:
The user can click any circle and an informational window will pop up (as shown above) that provides the eclipse type, its Saros number, the duration of the eclipse, and at what locations on the Earth it will be visible.

Tidal Bulge Simulator

Main Purpose:
This simulator allows the user view and investigate the causes of the tides on the Earth.

Image:
The image displays the Earth with its current tidal bulges. Also shown is the Moon in its orbit around the Earth and an indication that the Sun is far off to the right of the screen.

Controls:
At the lower right, the user can start and stop the simulated motion by clicking the "run" button.

The user can also click on and off the effects of the Sun, which determines if various spring and neap tides will be displayed, and click on and off the effects of Earth's rotation, which determines if the tidal bulges are displayed co-linear with the Moon's location or not.

Section 6: *Image Resources*

This section contains list of the astronomical images included in this module. Included is a brief description of each image. The intent of each image is to supplement and support the discussions generated by the questions presented in this module, which in turn will hopefully lead to a better understanding of the astronomical topics and concepts involved.

Images

Lunar Phases - Drawing: An image of the Moon in its orbit around the Earth with the various lunar phases labeled accordingly.

Lunar Phases - Images: An image of the Moon in its orbit around the Earth with the various lunar phases labeled accordingly. Also included is information regarding how many days old a specific phase is from the new moon phase, and when certain phases rise and set as seen from the Earth.

Lunar Sidereal Period: An image that visually displays the definition of a sidereal period.

Lunar Synodic Period: An image that visually displays the definition of a synodic period.

Lunar Rotation: An image of the Moon in its orbit around the Earth emphasizing that the Moon does rotate in order to keep the same side always orientated towards the Earth.

Tides: Two images of the Earth, Moon, and Sun displaying the specific configurations necessary for spring and neap tides.

Types of Shadow: An image that displays the types of shadows that can be produced by an object by a large and distant light source. Emphasis is on the umbra, penumbra, and the extent of these types of shadows beyond the object.

Lunar Eclipse I: An image of a total lunar eclipse with the umbra and penumbra parts of the shadow labeled, indicating where a total or partial eclipse will be seen respectively.

Lunar Eclipse II: Another image of a total lunar eclipse. Also included is a small photograph of the Moon during such an eclipse.

Total Solar Eclipse: An image of a solar eclipse with the umbra and penumbra parts of the shadow labeled, indicating where a total or partial eclipse will be seen respectively.

Annular Solar Eclipse: An image of a solar eclipse with the umbra and penumbra parts of the shadow labeled, indicating where an annual or partial eclipse will be seen respectively.

Solar Eclipses: Images a) and b) display a solar eclipse with the umbra and penumbra parts of the shadow labeled, indicating where a total or partial eclipse will be seen respectively. Image c) displays a solar eclipse with the umbra and penumbra parts of the shadow labeled, indicating where an annual or partial eclipse will be seen respectively. All images also include small photographs of the various types of eclipses.

Total Solar Eclipse Image: A photograph of the Moon and Sun during a total solar eclipse. The corona of the sun is dramatic.

Annular Solar Eclipse Image: A photograph of the Moon and Sun during an annular solar eclipse.

Solar Eclipse Paths: A map of the Earth displaying the dates and paths of various total and annular solar eclipses occurring 2000 - 2020.

Line of Nodes: An image of the Moon in its orbit around the Sun emphasizing the intersection of the ecliptic plane and the tilted plane of the Moon's orbit (the line of nodes).

Eclipse Seasons: Image a) displays close up configurations of the Earth and Moon of when a solar and lunar eclipse will or will not occur during the new and full moon phases respectively. Image b) displays the Moon in its orbit around the Earth as well as the Earth in orbit around the Sun. Emphasis in on when the configurations noted in Image a) will occur during the yearly revolution of the Earth.

Section 7: *Outline Resources*

This section contains list of the astronomical outlines included in this module. Included is a brief description of the contents of each outline. The intent of each outline is to supplement and support the discussions generated by the questions presented in this module, which in turn will hopefully lead to a better understanding of the astronomical topics and concepts involved.

Each outline can be supplied to the student before class in order to prepare for the astronomical topic to be discussed, or can be supplied and/or shown during class to provide a reference for the discussion.

Outlines

Phases of the Moon: A listing of the eight named phases of the Moon, how much of the Moon is illuminated, and on which side of the Moon the illumination occurs as seen from Earth.

Rising/Meridian/Setting Times: A listing of the rising, meridian, and setting times for the eight phases of the moon. This chart assumes that both the sun and moon are on the celestial equator, so it is not particularly accurate.

Lunar Periods: The definition and time interval of a lunar sidereal and lunar synodic period.

Lunar Eclipses: Brief descriptions of where the Moon is located inside of the shadow of the Earth for total lunar, partial lunar, and penumbral lunar eclipses.

Solar Eclipses: Brief descriptions of what an observer on the surface of the Earth will see in the sky during total solar, partial solar, and annular solar eclipses.

Tides: A description of the causes of tides and why the effects of the moon dominate those of the sun. Covers neap and spring tides as well.