ClassAction: Coordinates and Motions 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.
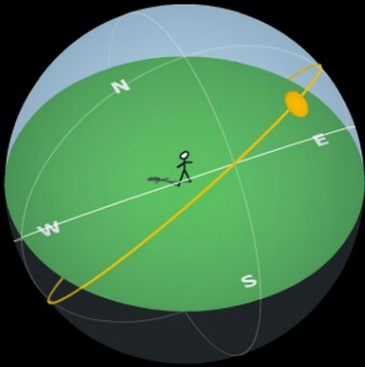
The Path of the Sun 1

Key Concept: Yearly and daily motion of the Sun

Secondary Concepts: Ecliptic; Celestial Sphere

Description:
The image above displays a person standing on a mid-northern latitude local horizon system inside a celestial sphere. The local cardinal directions are labeled, while the local meridian and celestial equator are simple represented with white lines on the celestial sphere. The Sun shown is animated and appears to have the diurnal motion represented by the yellow line. Students should determine if there is anything wrong with the animated sun's path.

Answer:
While the Sun appears to move along the ecliptic path, which indeed crosses the celestial equator, throughout the year, the Sun's daily motion will always remain essentially parallel to the celestial equator. To put it another way: over the course of a day, the Sun's essentially maintains the same declination value. Therefore, on the day of vernal equinox, the Sun's will follow a path that is 23.5^o above the celestial equator. Thus:

The animation shows the Sun rising at about 23.5^o above the celestial equator but setting about 23.5^o below the celestial equator, which is impossible.

Suggestions:
Recommended animations: Sun's Rays Simulator; Draggable Sun Demonstrator; Ecliptic Simulator.

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.

Sledding or Going to the Beach

Key Concept: The Obliquity of the Earth

Secondary Concepts: The Seasons; Coordinates on the Earth; Geography

Description:
The image displays people as either sledding (as shown) or at the beach and are indicated as being at a specific location on the Earth. Students should determine what month during the year the activity shown would be possible at that specific location.

Answer:
Because of the Earth's revolution around the Sun and the obliquity of the Earth, the axis of rotation of the Earth will have a specific orientation with respect to the Sun depending on where the Earth is in its orbit. Because of this, the Earth undergoes seasons throughout the year. Winter begins in the northern hemisphere and summer in the southern hemisphere when the axis of the Earth is orientated away from the Sun (late December – late March).   Summer occurs in the northern hemisphere and winter in the southern hemisphere when the axis of the Earth is orientated towards from the Sun (late June – late September). Sledding would naturally occur during the winter season and going to the beach would occur during the summer season.   Thus:

Sledding (Going to the Beach) in Germany and Canada, both in the northern hemisphere, occurs in January (July).
Sledding (Going to the Beach) in Chile and New Zealand, both in the southern hemisphere, occurs in July (January).

Suggestions:
There are 8 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: Obliquity Simulator; Sun's Rays Simulator.

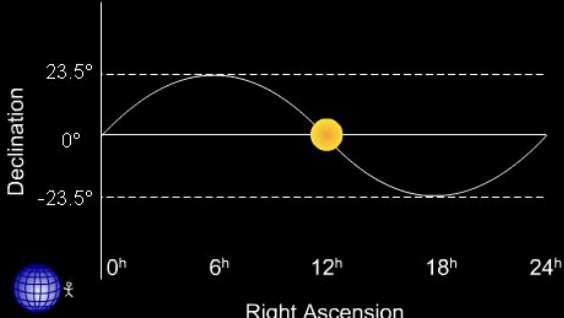Recommended images: Seasons.

Difficulty: 2

Sun on the Ecliptic 1

Key Concept: The Ecliptic

Secondary Concepts: Right Ascension / Declination; Celestial Sphere; Equinox and Solstice; Seasons

Description:
The image above displays a graph of Declination versus Right Ascension. The curved line represents the ecliptic and the Sun is depicted at a specific location on the ecliptic. Students should determine at which date the Sun would have the depicted ecliptic location on the graph.

Answer:
Because of the Earth's revolution around the Sun and the obliquity of the Earth, the axis of rotation of the Earth will have a specific orientation with respect to the Sun depending on where the Earth is in its orbit. Because of this, the Earth undergoes seasons throughout the year. From the point of view of the Earth, this motion and the orientations will appear as the Sun moving along the ecliptic. When the Earth's axis of rotation is orientated towards the Sun, this corresponds to the Sun appearing to be located at a greater declination on the celestial sphere. The maximum declination achieved by the Sun occurs at the summer solstice – the beginning of summer (June 21). When the Earth's axis of rotation is orientated away from the Sun, this corresponds to the Sun appearing to be located at a lesser declination on the celestial sphere. The minimum declination achieved by the Sun occurs at the winter solstice – the beginning of winter (Dec. 21). When the Earth's axis of rotation is orientated neither towards nor away from the Sun, this corresponds to the Sun appearing to be located at a zero declination on the celestial sphere. This orientation will occur at the vernal equinox – the beginning of spring (Mar. 21), and the autumnal equinox – the beginning of fall (Sept. 21). The zero point of right ascension is set by the location of the Sun at the vernal equinox. Thus:

Date 1 corresponds to the autumnal equinox – Sept. 21.
Date 2 corresponds to the winter solstice – Dec. 21.

Date 3 corresponds to the summer solstice – June 21.
Date 4 corresponds to the vernal equinox – Mar. 21.

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: Ecliptic Simulator; Sun's Rays Simulator; Draggable Sun
    Demonstrator; Union Seasons Demonstrator.

Recommended images: Ecliptic; Solar Motion.

Recommended outlines: Ecliptic; Celestial Equatorial Coordinates.

Difficulty: 3

Sun on the Ecliptic 2

Key Concept: The Ecliptic

Secondary Concepts: Right Ascension / Declination; Celestial Sphere; Equinox and Solstice; Seasons

Description:

The image above displays a graph of Declination versus Right Ascension. The curved line represents the ecliptic and the Sun is initially depicted at a specific location on the ecliptic. By clicking the "Run Animation" button, the Sun will move along the ecliptic and stop at a different location. Students should determine which range of dates would correspond to the presented motion of the Sun along the ecliptic on the graph.

Answer:

Because of the Earth's revolution around the Sun and the obliquity of the Earth, the axis of rotation of the Earth will have a specific orientation with respect to the Sun depending on where the Earth is in its orbit. Because of this, the Earth undergoes seasons throughout the year. From the point of view of the Earth, this motion and the orientations will appear as the Sun moving along the ecliptic. When the Earth's axis of rotation is orientated towards the Sun, this corresponds to the Sun appearing to be located at a greater declination on the celestial sphere. The maximum declination achieved by the Sun occurs at the summer solstice – the beginning of summer (June 21). When the Earth's axis of rotation is orientated away from the Sun, this corresponds to the Sun appearing to be located at a lesser declination on the celestial sphere. The minimum declination achieved by the Sun occurs at the winter solstice – the beginning of winter (Dec. 21). When the Earth's axis of rotation is orientated neither towards nor away from the Sun, this corresponds to the Sun appearing to be located at a zero declination on the celestial sphere. This orientation will occur at the vernal equinox – the beginning of spring (Mar. 21), and the autumnal equinox – the beginning of fall (Sept. 21). The zero point of right ascension is set by the location of the Sun at the vernal equinox. Thus:

*Range 1 corresponds to a transition from the vernal equinox to the summer solstice –
Mar. 21 to June 21.*
*Range 2 corresponds to a transition from the autumnal equinox to the winter solstice –
Sept. 21 to Dec. 21.*
*Range 3 corresponds to a transition from the summer solstice to the autumnal equinox –
June. 21 to Sept. 21.*
*Range 4 corresponds to a transition from the vernal equinox to the autumnal equinox –
Mar. 21 to Sept. 21.*

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: Ecliptic Simulator; Sun's Rays Simulator; Draggable Sun Demonstrator; Union Seasons Demonstrator.

Recommended images: Ecliptic; Solar Motion.

Recommended outlines: Ecliptic; Celestial Equatorial Coordinates.

Difficulty: 3

Sun at Zenith 1

Key Concept: Celestial Sphere

Secondary Concepts: Right Ascension / Declination; Latitude / Longitude; The Ecliptic; Zenith

Description:
The image above displays a graph of Declination versus Right Ascension. The curved line represents the ecliptic and the Sun is depicted at a specific location on the ecliptic. Students should determine at which latitude the Sun would be zenith for the date depicted by the Sun's ecliptic location on the graph.

Answer:
The celestial sphere is defined relative to the Earth. For example, the north celestial pole (NCP) is the location in space directly above the Earth's north pole, the south celestial pole (SCP) is the location in space directly above the Earth's south pole, and the celestial equator (CE) marks in locations in space directly above Earth's own equator. Declination is a coordinate referencing how far north or south a location in space is relative to the celestial equator. By convention, all locations on the celestial equator are at 0° declination so that the NCP is at $+90^o$ declination, and the SCP at -90° declination. This means that for a person who lives at the north pole (90° N latitude), the location in space directly above them, their zenith, would be the NCP and $+90^o$ declination. Similarly, for a person who lives at the south pole (90° S latitude), the location in space directly above them, their zenith, would be the SCP and -90° declination. Finally, for anyone who lives at the Earth's equator (0° latitude), the location in space directly above them, their zenith, would have to be on the CE and 0° declination. This logic can be extended such that the zenith for all northern latitudes would have the positive declination value of the latitude, and that the zenith for all southern latitudes would have the negative declination value of the latitude. Thus:

Date 1 with the Sun at 0° declination would be at zenith for latitude 0°.
Date 2 with the Sun at -20° declination would be at zenith for latitude 20° S.

Date 3 with the Sun at +20° declination would be at zenith for latitude 20° N.
Date 4 with the Sun at -10° declination would be at zenith for latitude 10° S.
Date 5 with the Sun at +20° declination would be at zenith for latitude 20° N.

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: Draggable Sun Demonstrator; Paths of the Sun Demonstrator; Right Ascension / Declination Demonstrator; Meridinal Altitude Simulator.

Recommended images: Ecliptic; Solar Motion.

Recommended outlines: Ecliptic; Celestial Equatorial Coordinates; Terrestrial Coordinates.

Hints:
Perhaps ask the students to imagine themselves to be at the north pole, south pole, or equator and deduce what declination the point in space directly above them would have.

Difficulty: 4

Declination Ranges

Key Concepts: Declination; Circumpolar stars

Secondary concepts: Latitude; Zenith; Sidereal motion

Description:
An incomplete statement is presented that indicates a latitude of a specific location on the Earth, the declination of a specific star. Students should determine whether the star is a circumpolar star, a never rise star, or a rise and set star for that location on the Earth. Initially, there is no image displayed on the screen.

Answer:
All stars appear to rotate in circles around the north celestial pole (NCP) because of the actual diurnal rotation the Earth. For a star to be considered a circumpolar star, it must always be in the sky at a given location on the Earth. Consider a person at the Earth's north pole. Their zenith at 90° N latitude would be the NCP ($+90^o$ declination) and the locations in space above their horizon would be located on the celestial equator (0° declination). As a result, when the stars and the celestial sphere rotate through the course of the day, none of the stars will set. Therefore, with no offset between zenith and the NCP, all stars from $+0^o$ to $+90^o$ declination will be circumpolar stars, and all stars from 0° to -90° declination will never rise. For a person at 80° N latitude, now the NCP is offset from their zenith by 10° and the locations in space above their horizon will range in declination from $+10^o$ to -10°. As a result, only those stars that exist between $+10^o$ to $+90^o$ declination will be circumpolar, those in ± offset range will rise and set, and those from -10° to -90° declination will never rise. This logic can be extended to all northern latitudes on the Earth such that the ± offset range with correspond to the declinations of the rise and set stars, the stars with a declination from the positive offset value to $+90^o$ declination will be circumpolar stars, and the stars with a declination from the negative offset value to -90° declination will never rise. For a location on the Earth with a southern latitude, the offset should be determined with respect to the south celestial pole,

with the stars with a declination from the negative offset value to -90° being circumpolar stars, and the stars with a declination from the positive offset value to +90° declination never rising. Thus:

For Havana, Cuba at 23° N latitude, the offset is 67°; so stars with declinations between $\pm$67° will rise and set, with +67° to +90° declinations will be circumpolar, and with -67° to -90° will never rise. Therefore, Sirius is a rise and set star, Betelguese is a rise and set star, Capella is a rise and set star, and Rigel is a rise and set star.

For Taymyr Island, Russia at 78° Nlatitude, the offset is 12°; so stars with declinations between $\pm$ 12° will rise and set, with +12° to +90° declinations will be circumpolar, and with -12° to -90° will never rise. Therefore, Sirius is a never rise star, Betelguese is a rise and set star, Capella is a circumpolar star, and Rigel is a rise and set star.

For Manila, Philippines at 15° N latitude, the offset is 75°; so stars with declinations between $\pm$ 75° will rise and set, with +75° to +90° declinations will be circumpolar, and with -75° to -90° will never rise. Therefore, Sirius is a rise and set star, Betelguese is a rise and set star, Capella is a rise and set star, and Rigel is a rise and set star.

For Byrd Station, Antarctica at 80° S latitude, the offset is 10°; so stars with declinations between $\pm$ 10° will rise and set, with -10° to -90° declinations will be circumpolar, and with +10° to +90° will never rise. Therefore, Sirius is a circumpolar star, Betelguese is a rise and set star, Capella is a never rise star, and Rigel is a rise and set star.

For Sanae, Antarctica at 70° S latitude, the offset is 20°; so stars with declinations between $\pm$ 20° will rise and set, with -20° to -90° declinations will be circumpolar, and with +20° to +90° will never rise. Therefore, Sirius is a rise and set star, Betelguese is a rise and set star, Capella is a never rise star, and Rigel is a rise and set star.

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: Declination Ranges Simulator.

Recommended images: Declination.

Recommended outlines: Declination Ranges; Celestial Equatorial Coordinates.

Hints:
This question provides hints in the form of images of a person standing at a given location on the Earth, the location's horizon, and the declination values of the celestial sphere as a reference frame. The images also display via color codes the declinations of the rise and set stars, the circumpolar stars, and the never rise stars for a given location. These hints essentially give the answer to the student who knows how to interpret the image.

Difficulty: 5 (with hints: 2)

Right Ascension & Declination Ranges

Key Concept: Right Ascension / Declination

Secondary Concepts: Celestial Sphere; The Ecliptic

Description:
A question is presented that offers 5 different sets of right ascension (RA) and declination (Dec) coordinates. Students should determine which set of coordinates is closest to a given location on the celestial sphere. Initially, there is no image displayed on the screen.

Answer:
Locations in space are identified using the right ascension and declination coordinates on the celestial sphere. The celestial sphere is defined relative to the Earth. For example, the north celestial pole (NCP) is the location in space directly above the Earth's north pole, the south celestial pole (SCP) is the location in space directly above the Earth's south pole, and the celestial equator (CE) marks in locations in space directly above Earth's own equator. Declination (abbreviated with a δ) is a coordinate referencing how far north (towards NCP) or south (towards SCP) a location in space is relative to the celestial equator. By convention, all locations on the celestial equator are at 0° declination so that the NCP is at $+90^o$ declination, and the SCP at -90° declination. Right ascension (abbreviated with an α) is a coordinate referencing how far east a location in space is relative to the vernal equinox. By convention, the vernal equinox is at 0 hours of RA, the summer solstice at 6 hours of RA, the autumnal equinox at 12 hours of RA, and the winter solstice at 18 hours of RA. The range of RA values is from 0 h to 24 h. Thus:

The south celestial pole ($\delta = -90^o$, $\alpha = 0$ to 24 h) is closest to $\alpha = 14$ h, $\delta = -88^o$.
The celestial equator ($\delta = 0^o$, $\alpha = 0$ to 24 h) is closest to $\alpha = 23$ h, $\delta = +2^o$.
The ecliptic ($\delta = +23.5^o$ to -23.5^o, $\alpha = 0$ to 24 h) is closest to $\alpha = 6$ h, $\delta = +24^o$.
The north celestial pole ($\delta = +90^o$, $\alpha = 0$ to 24 h) is closest to $\alpha = 14$ h, $\delta = +88^o$.
The vernal equinox ($\delta = 0^o$, $\alpha = 0$ h) is closest to $\alpha = 23$ h, $\delta = +2^o$.

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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: Right Ascension / Declination Simulator; Simplified RA / Dec Simulator.

Recommended images: Declination; Right Ascension; Celestial Sphere; Ecliptic.

Recommended outlines: Celestial Equatorial Coordinates; Ecliptic.

Hints:
This question provides hints in the form of images displaying the locations of the various choices on the celestial sphere. The celestial equator is also labeled as a reference. Simply comparing the option location (A, B, C, D, or E) to the given location (south celestial pole, celestial equator, etc.) should provide a correct solution.

Difficulty: 3 (with hints: 1)

Terrestrial Coordinates

Key Concept: Latitude / Longitude

Secondary Concept: Geography

Description:
A fill in the blank question is presented that provides the name of a city and its coordinates of latitude and longitude. Students should determine which country the city is located based upon these provided coordinates.

Answer:
Latitude is a coordinate referencing how far north or south a given location on the Earth is with respect to the equator. By convention, all locations on the equator are at 0° latitude so that the north pole is at 90° N, and the south pole at 90° S. Longitude is a coordinate referencing how far east or west a given location on the Earth is with respect to the prime meridian, which is an arc of a great circle that connect the north pole to the south pole through Greenwich, England. By convention, all locations on the prime meridian are at 0° longitude and longitude values range from 0° to 180° east or west. Thus:

Perm is in the country of Russia.
Monclova is in the country of Mexico.
Fortaleza is in the courtry of Brazil.
Yeppoon is in the country of Australia.
Arbory is in the country of Canada.

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: Latitude / Longitude Simulator.

Recommended images: Time Zones; Terrestrial Coordinates.

Recommended outlines: Terrestrial Coordinates.

Hints:
Having a world map or globe handy would allow the student who is unfamiliar with geography to better deduce the country of origin for a given city.

Difficulty: 2

Azimuth & Altitude Coordinates

Key Concept: Azimuth / Altitude

Secondary Concepts: Celestial Sphere; Zenith; Meridian

Description:
A question is presented that provides a given location in the sky or in space. Students should determine which set of local azimuth and altitude coordinates are closest to the provided location.

Answer:
Altitude and azimuth are coordinates that are typically used for referencing locations in the sky or space relative to a local hemisphere of view on the Earth (a.k.a., a local horizon system). Altitude is a coordinate referencing how far above the horizon a given location is. By convention, the all locations on the horizon are 0° altitude and the zenith is $+90^o$. Azimuth is a coordinate that references how far east or west a given location is with respect to the local cardinal direction of north (a.k.a., the north point). By convention, going east is in the positive direction so that the east point is 90° azimuth, the south point is 180°, and the west point is 270° (or -90°). The range of azimuth values is from 0° to 360°. The question implies using the student's local horizon system (so for Nebraska, a system at about 41° N latitude). Also, the northern latitude value for a location on the surface of the Earth is equal to the altitude value for the north celestial pole (and Polaris) for that location local horizon system. Thus:

The north point (Az. = 0°, Alt. = 0°,) is closest to Az. = 358°, Alt. = -2°.
The zenith point (Az. = 0° to 360°, Alt. = $+90^o$) is closest to Az. = 181°, Alt. = 88°.
The north celestial pole (Az. = 0°, Alt. = $+41^o$) is closest to Az. = 2°, Alt. = 39°.
The intersection of the observer's meridian and the celestial equator (Az. = 180°, Alt. = 49°) is closest to Az. = 177°, Alt. = 50°.
The west point (Az. = 270°; Alt. = 0°) is closest to Az. = 272°, Alt. = 8°.

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: Azimuth / Altitude Demonstrator; Meridian Altitude Simulator.

Recommended outlines: Horizon Coordinates.
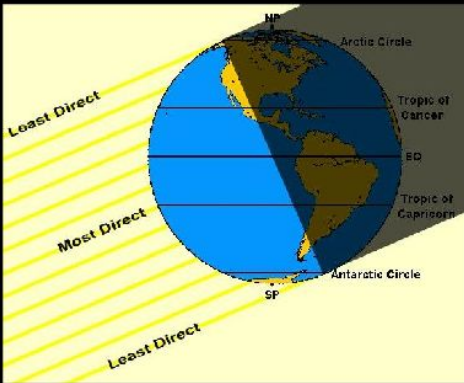
Difficulty: 3

The Sun's Rays

Key Concept:
The Seasons

Secondary Concepts:
Equinox and Solstice

Description:
An image is displayed that depicts the Earth being hit by the Sun's rays at a given time during the year. Students should determine at what approximate date the Sun's rays would hit the Earth as depicted.

Answer:
Because of the Earth's revolution around the Sun and the obliquity of the Earth, the axis of rotation of the Earth will have a specific orientation with respect to the Sun depending on where the Earth is in its orbit. Because of this, the Earth undergoes seasons throughout the year. Winter begins in the northern hemisphere (summer in the southern hemisphere) when the axis of the Earth is at a maximum orientation of 23.5^o away from the Sun (December 21).   Summer begins in the northern hemisphere (winter in the southern hemisphere when the axis of the Earth is at a maximum orientation of 23.5^o towards from the Sun (June 21). Spring and autumn begin when there is no orientation towards or away from the Sun (March 21 and September 21). All other times during the year correspond to an orientation of the axis of rotation somewhere between these extremes. Thus:

Image 1, with the axis of rotation at a maximum orientation away from the Sun, corresponds to Dec. 21.
Image 2, with the axis of rotation having an orientation neither towards nor away from the Sun, should correspond to September 21.
Image 3, with the axis of rotation to a lesser extent orientated away from the Sun, corresponds to Oct. 21 or Feb. 21.

Image 4, with the axis of rotation to a lesser extent orientated toward the Sun,
corresponds to Apr. 21 or Aug. 21.
Image 5, with the axis of rotation at a maximum orientation toward the Sun, corresponds
to Jun. 21.

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: Obliquity Simulator; Sun's Rays Simulator.

Recommended images: Seasons; Ecliptic.

Recommended outlines: Parallels of Latitude; Ecliptic.

Hints:
Perhaps have the student tilt his / her head sideways until the Sun's rays appear
horizontal. This may allow them to more easily deduce the extent of the axis of
rotation's orientation towards or way from the Sun.

Difficulty: 2

Altitude of the Pole

Key Concept:
Azimuth / Altitude

Secondary Concepts:
Celestial Sphere; Latitude / Longitude

Description:
A fill in the blank question is presented that provides latitude of a given location on the surface of the Earth and a location of one of the celestial poles (north or south). Students should determine at which value of altitude above the cardinal direction of north (a.k.a., the north point) one of the celestial poles would have from the given location on the Earth. Initially, there is no image displayed on the screen.

Answer:
Consider a person located at the north pole (latitude = 90° N). They would perceive the north celestial pole (NCP) directly above them (at zenith) with a local altitude value of $+90^o$. For a person located on the equator (latitude = 0°), they would perceive the NCP and the south celestial pole (SCP) on the horizon with a local altitude value of 0°. This logic can be extended such that the value of the latitude for a certain location on the Earth is equal to the local altitude value for the NCP (or SCP if the location is in the southern hemisphere). Thus:

From latitude 90° N, the NCP has altitude = 90°.
From latitude 70° N, the NCP has altitude = 70°.
From latitude 45° N, the NCP has altitude = 45°.
From latitude 20° N, the NCP has altitude = 20°.
From latitude 0° N, the NCP has altitude = 0°.
From latitude 90° S, the SCP has altitude = 90°.
From latitude 65° S, the SCP has altitude = 65°.
From latitude 45° S, the SCP has altitude = 45°.
From latitude 25° S, the SCP has altitude = 25°.

From latitude 0° S, the SCP has altitude = 0°.

Suggestions:
There are 10 different adaptations to the question (5 for latitudes in northern hemisphere; 5 for latitudes in southern hemisphere), 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.

A lecture suggestion is to take advantage of a local planetarium to discuss the equivalency of latitude and altitude of the NCP or SCP.

Recommended animations: Azimuth / Altitude Demonstrator; Meridian Altitude Simulator.

Recommended images: Terrestrial Coordinates.

Recommended outlines: Meridinal Altitude; Terrestrial Coordinates; Celestial Equatorial Coordinates; Horizon Coordinates.

Hints:
This question provides hints in the form of images displaying the local hemisphere for a given latitude, and the locations of the zenith, the NCP or SCP, and the celestial equator. These hints essentially give the answer to the student who knows how to interpret the image.

Also, perhaps show the student a picture of the night sky in Nebraska and have them determine the altitude of Polaris (approximately where the NCP is located). Then, provide a globe and have them determine the latitude of Nebraska on the Earth.

Difficulty: 3 (with hints: 1)

Meridinal Altitude for the Sun

Key Concepts: Azimuth / Altitude; Equinox and Solstice

Secondary Concepts: Declination / Right Ascension; Latitude / Longitude

Description:
A question is presented that provides the latitude coordinate for a location on the surface of the Earth and a specific location in space – namely, an equinox or a solstice. Students should determine the maximum meridinal altitude of the Sun when it occupies the given location in space. Initially, there is no image displayed on the screen.

Answer:
The value of the latitude for a certain location on the Earth is equal to the local altitude value for the NCP. The celestial equator (CE) would be all locations that are 90° offset from the NCP. With respect to the local horizon system, this means that the CE would have a meridinal altitude (a.k.a., altitude along the meridian) value of 90° <u>minus latitude</u>. A specific solstice is either 23.5^o below or above the CE, which would have to be subtracted or added to the meridinal altitude of the CE accordingly. (Please note that altitude has a maximum value of $+90^o$; therefore, if the calculated meridinal altitude is greater than $+90^o$, then this calculated value should be subtracted from 180° in order to obtain the corrected meridinal altitude.) Either equinox is located on the CE, so no addition calculations are necessary. Thus:

At 60° N latitude, the meridinal altitude of the: vernal and autumnal equinox is 30°; the summer solstice is 53.5^o; and the winter solstice is 6.5^o.
At 45° N latitude, the meridinal altitude of the: vernal and autumnal equinox is 45°; the summer solstice is 68.5^o; and the winter solstice is 21.5^o.
At 30° N latitude, the meridinal altitude of the: vernal and autumnal equinox is 60°; the summer solstice is 83.5^o; and the winter solstice is 36.5^o.

At 15° N latitude, the meridinal altitude of the: vernal and autumnal equinox is 75°; the summer solstice is 81.5^o; and the winter solstice is 51.5^o.

At 0° N latitude, the meridinal altitude of the: vernal and autumnal equinox is 90°; the summer solstice is 66.5^o; and the winter solstice is 66.5^o.

Suggestions:

There are 20 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: Meridian Altitude Simulator; Paths of the Sun Demonstrator.

Recommended images: Terrestrial Coordinates; Ecliptic.

Recommended outlines: Meridinal Altitude; Terrestrial Coordinates; Celestial Equatorial Coordinates; Horizon Coordinates; Ecliptic.

Hints:

This question provides hints in the form of images displaying the local hemisphere for a given latitude, and the locations of the zenith, the NCP, the celestial equator, and the Sun. These hints essentially give the answer to the student who knows how to interpret the image.

Difficulty: 4 (with hints: 2)
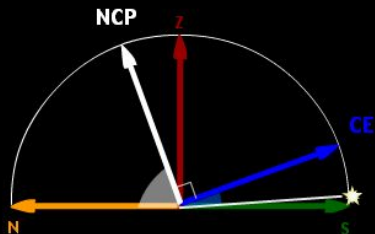
Meridinal Altitude for the Stars

Key Concept: Azimuth / Altitude; Declination / Right Ascension

Secondary Concepts: Latitude / Longitude

Description:
A question is presented that provides the latitude coordinate for a location on the surface of the Earth and the declination coordinate for a specific star in space. Students should determine the maximum meridinal altitude of the star when it occupies the given location in space. Initially, there is no image displayed on the screen.

Answer:
The value of the latitude for a certain location on the Earth is equal to the local altitude value for the NCP (or SCP if the location is in the southern hemisphere). The celestial equator (CE) would be all locations that are 90° offset from a celestial pole. With respect to the local horizon system, this means that the CE would have a meridinal altitude (a.k.a., altitude along the meridian) value of 90° minus latitude. Since declination references how far something is above (toward NCP) or below (toward SCP) the CE, a specific star's declination would have to be subtracted or added to the meridinal altitude of the CE accordingly. (Please note that altitude has a maximum value of +90°; therefore, if the calculated meridinal altitude is greater than +90°, then this calculated value should be subtracted from 180° in order to obtain the corrected meridianal altitude.) Thus:

At 70° N latitude, the meridinal altitude of: Sirius is 4°; Betelguese is 27°; and Capella is 66°.
At 55° N latitude, the meridinal altitude of: Sirius is 19°; Betelguese is 42°; and Capella is 77°.
At 15° N latitude, the meridinal altitude of: Sirius is 59°; Betelguese is 82°; and Capella is 59°.

At 0° N latitude, the meridinal altitude of: Sirius is 74°; Betelguese is 83°; and Capella is 44°.

At 35° S latitude, the meridinal altitude of: Sirius is 71°; Betelguese is 48°; and Capella is 9°.

At 50° S latitude, the meridinal altitude of: Sirius is 56°; Betelguese is 33°; and Capella is -6°.

Suggestions:
There are 18 different adaptations to the question (5 for latitudes in northern hemisphere; 5 for latitudes in southern hemisphere), 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: Meridian Altitude Simulator; Paths of the Sun Demonstrator.

Recommended images: Terrestrial Coordinates; Ecliptic.

Recommended outlines: Meridinal Altitude; Terrestrial Coordinates; Celestial Equatorial Coordinates; Horizon Coordinates; Ecliptic.

Hints:
This question provides hints in the form of images displaying the local hemisphere for a given latitude, and the locations of the zenith, the NCP, the celestial equator, and the named star. These hints essentially give the answer to the student who knows how to interpret the image.

Difficulty: 4 (with hints: 2)

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.

Seasons at the Union

Description:
The images above display photographs taken in chronological order of the Nebraska Student Union on 4 specific days of the year – (in no particular order) the vernal equinox, the autumnal equinox, the winter solstice, and the summer solstice. Students should determine which photograph corresponds to the selected day.

Answer:
When the Earth's axis of rotation is orientated towards the Sun, this corresponds to the Sun appearing to be located at a greater declination on the celestial sphere. The maximum declination achieved by the Sun occurs on the summer solstice – the beginning of summer (June 21). In the northern hemisphere, this is also when the Sun would be highest in the sky at noon and any shadows would be at a minimum length. When the Earth's axis of rotation is orientated away from the Sun, this corresponds to the Sun appearing to be located at a lesser declination on the celestial sphere. The minimum declination achieved by the Sun occurs on called the winter solstice – the beginning of winter (Dec. 21). In the northern hemisphere, this is also when the Sun would be lowest in the sky at noon and any shadows would be at a maximum length. When the Earth's axis of rotation is orientated neither towards nor away from the Sun, this corresponds to the Sun appearing to be located at a zero declination on the celestial sphere. This orientation will occur at the vernal equinox – the beginning of spring (Mar. 21), and the autumnal equinox – the beginning of fall (Sept. 21). For either hemisphere this is when the Sun at noon is exactly in-between its maximum and mininum height in the sky, and any shadows are exactly in-between their maximum and minimum lengths. The photographs are in chronological order, thus:

Photograph A is a photo taken when the Sun is at summer solstice.
Photograph B is a photo taken when the Sun is at autumnal equinox.
Photograph C is a photo taken when the Sun is at winter solstice.
Photograph D is a photo taken when the Sun is at winter solstice.

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: Union Seasons Demonstrator; Paths of the Sun Demonstrator; Sun's Rays Simulator.

Recommended images: Ecliptic; Seasons.

Difficulty: 2

Sun at Zenith 2

Key Concept: Celestial Sphere

Secondary Concepts: Right Ascension / Declination; Latitude / Longitude; The Ecliptic; Zenith; The Tropic of Cancer

Description:
An incomplete statement is presented that indicates that the Sun should be at zenith at noon for a certain location on the Earth some time during the year. Students should determine where that location is on the Earth. Initially, there is no image displayed on the screen.

Answer:
As noted in the answer to the previous question, the zenith for all northern latitudes would have the positive declination value of the latitude, and that the zenith for all southern latitudes would have the negative declination value of the latitude. Over the course of a year, the Sun appears to move along the ecliptic and as a result will have declination values ranging from -23.5^o to +23.5^o. Therefore, only a location that has a latitude value within this range will be able to have the Sun at its zenith sometime during the year. Thus:

The person must be Hawaiian, since Hawaii has a latitude value of approximately 23.5^o. All other locations offered have latitudes greater than 23.5^o.

Suggestions:
Recommended animations: Draggable Sun Demonstrator; Paths of the Sun Demonstrator; Right Ascension / Declination Demonstrator; Meridinal Altitude Simulator.

Recommended images: Terrestrial Coordinates; Seasons.

Recommended outlines: Parallels of Latitude; Ecliptic.

Hints:
This question provides a hint in the form of an image of the world with the Tropic of Cancer delineated. The Tropic of Cancer denotes all locations on the Earth that have a latitude of 23.5^o N and only passes through Hawaii among the list of locations provided. If the student understands what the Tropic of Cancer represents, the answer becomes straightforward.

Difficulty: 4 (with hint: 2)

If a person is located at either 90° N or 90° S, the Sun's path would maintain a constant altitude throughout any given day (or not be seen at all). If a person was located at 0° latitude, the Sun's would rise and set perpendicularly with respect to the local horizon for every day of the year.

The images and location options are randomized for any selected day, therefore only the information above can be provided.

Suggestions:
There are many 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: Draggable Sun Demonstrator; Paths of the Sun
    Demonstrator.

Recommended images: Terrestrial Coordinates.

Recommended outlines: Terrestrial Coordinates; Celestial Equatorial Coordinates;
    Ecliptic.

Difficulty: 5

The Sun's Path 3

Key Concept: Yearly and daily motion of the Sun

Secondary Concepts: Ecliptic; Azimuth / Altitude; Latitude / Longitude; Right Ascension / Declination; Celestial Sphere

Description:
The image above displays a person's local horizon, the cardinal directions, the path of the Sun for an unknown day of the year, as well as faint lines denoting the ecliptic and the daily paths of the Sun when located $+23.5^o$ and -23.5^o declination. The latitude of the person on the surface of the Earth is also provided. Students should determine the day of the year based upon the data provided.

Answer:
The value of the latitude for a certain location on the Earth is equal to the local altitude value for the NCP (or SCP if the location is in the southern hemisphere). The celestial equator (CE) would be all locations that are 90° offset from a celestial pole. With respect to the local horizon system, this means that the CE would have a meridinal altitude (a.k.a., altitude along the meridian) value of 90° minus latitude. Properly comparing the Sun's meridinal altitude to the CE meridinal altitude provides the declination of the Sun. Since the range of declination values the Sun achieves throughout the year is known, a day of the year can be determined.

The images and day of the year options are randomized for any selected location, therefore only the information above can be provided.

Suggestions:
There are many 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: Draggable Sun Demonstrator; Paths of the Sun Demonstrator.

Recommended images: Terrestrial Coordinates.

Recommended outlines: Terrestrial Coordinates; Celestial Equatorial Coordinates; Ecliptic.

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.

Rising and Setting of the Stars

Key Concept: The Rotation and Revolution of the Earth

Secondary Concepts: Solar and Sidereal Time

Description:

The image above depicts the Earth at two locations in its orbit around the Sun that are one month apart. The fact that the stars rise and set four minutes earlier per day is provided. Students should determine how this amount would change if the rotation or revolution of the Earth increased or decreased.

Answer:

The rotation of the Earth is 23 hours and 56 minutes with respect to the fixed stars that are essentially fixed in space. In the course of rotating, though, the Earth also moves through space as it revolves around the Sun. As a result, after 23 hours and 56 minutes the Sun is not in the same location in the sky as it was previously (actually slightly east) and the Earth must rotate 4 minutes more for the Sun to appear in the same location in the sky. Therefore, with respect to the fixed stars the Sun rises and sets 4 minutes <u>later</u> with every rotation. Our measurement of time on Earth, though, is based upon the 24 hours it takes for the Sun to be in the same location in the sky, and therefore with respect to the Sun the stars rise and set 4 minutes <u>earlier</u> with every rotation. Thus:

If the rotation of the Earth increased (decreased), the amount of time it would take for the Earth to rotate so that the Sun would be in the same position would decrease (increase).

If the revolution of the Earth increased (decreased), the amount of time it would take for the Earth to rotate so that the Sun would be in the same position would increase (decrease).

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 allow the students to discuss in groups the solutions to the remaining adaptations.

Recommended images: Solar Day.

Hints:
Perhaps ask the students to imagine what it would be like if the Earth did not rotate and/or revolve around the Sun (without worrying about the Earth falling towards the Sun, of course).

Difficulty: 4

Seasons on Uranus

Key Concepts: The definition of obliquity; Seasons

Secondary Concepts: Latitude and Longitude

Description:
The image above depicts the Uranus at 4 different locations in its orbit around the Sun. Also included is the orientation of Uranus' axis of rotation with respect to the Sun and the date at which a depicted orientation will occur. Students should determine what type of season it would be like at various latitudes on Uranus at the different locations in its orbit.

Answer:
The obliquity is a measure of how much the axis of rotation of a planet is "tipped" with respect to the ecliptic plane for that planet. An obliquity of 0° indicates that the axis of rotation is perpendicular to the ecliptic plane. If the planet has an obliquity, in its revolution around the Sun the axis of rotation will have a specific orientation with respect to the Sun depending on where it is in it's orbit. Because of this, the planet will undergo seasons throughout its revolution. If the planet is tipped towards the Sun, the northern (southern) hemisphere will experience summer- (winter-) like conditions; and if the planet is tipped away from the Sun, the northern (southern) hemisphere will experience winter- (summer-) like conditions. The magnitude of the obliquity also will correspond to the extremity of the seasonal conditions. Thus:

In 1986/2070, the northern latitudes would experience an extreme summer and the southern latitudes an extreme winter.
In 2028, the southern latitudes would experience an extreme summer and the northern latitudes an extreme winter.
In 2007/2049, all latitudes would experience the same comparatively moderate spring (or fall).

Suggestions:
There are 4 different orbital locations depicted in the image, therefore the instructor could talk through and present the solutions to one or two locations and allow the students to discuss in groups the solutions to the remaining locations.

Recommended animations: Obliquity Simulator; Sun's Rays Simulator.

Recommended images: Seasons.

Hints:
Perhaps ask the students to imagine what the seasons would be like on the Earth if Earth's obliquity was 0°.

Difficulty: 4

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.

Meridinal Altitude Simulator
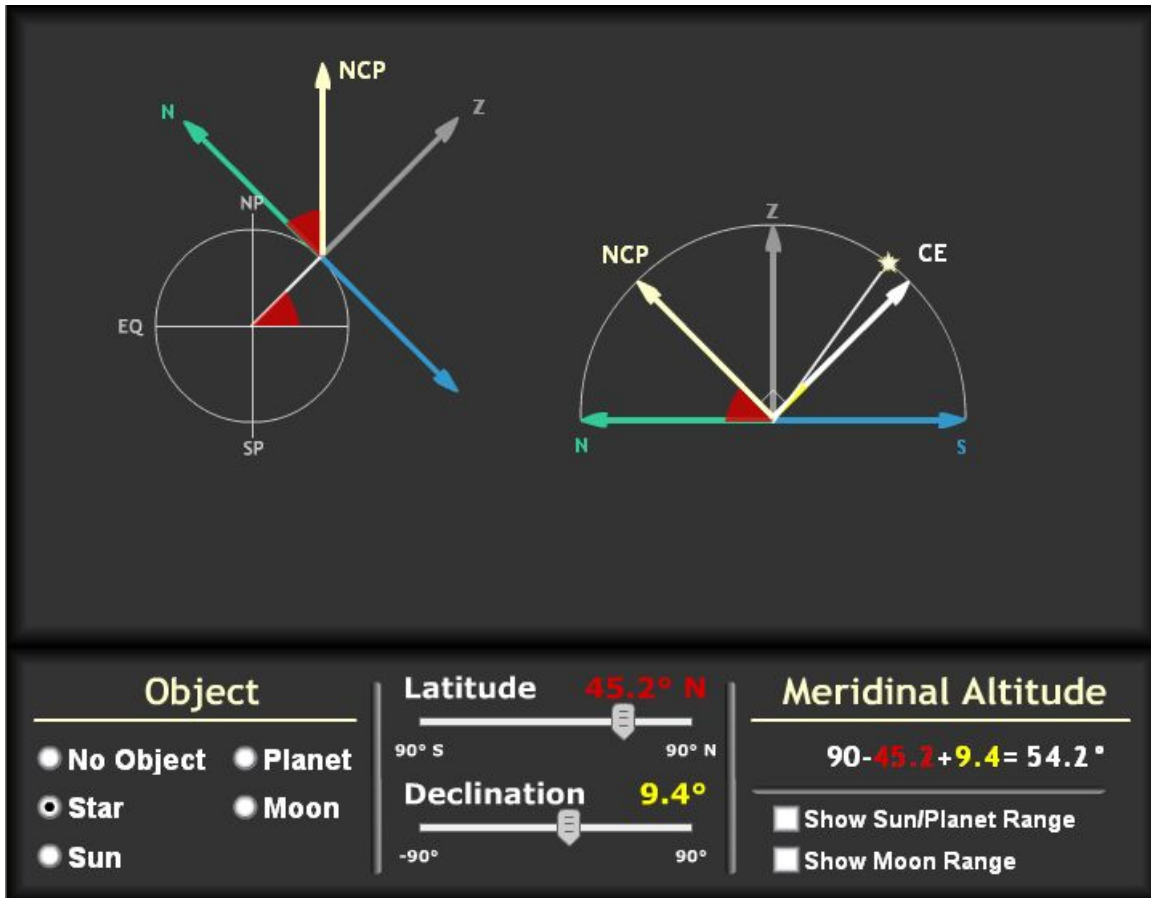
Main Purpose:
This simulator allows the user to determine the meridinal altitude of an object in the sky or space from any latitude on the Earth.

Images:
The image on the right displays the local horizon system for a selected latitude. The north celestial pole (NCP), the meridinal direction of the celestial equator, the local zenith, and the local cardinal directions of north and south are always displayed. If an object is selected, that object's position and declination angle (in yellow) are also displayed. The red angle represents the value of the latitude.

The image on the left displays the same local horizon system as is exists on the surface of the Earth. For this image, the north pole, south pole, and equator of the Earth are also denoted.

Controls:
When no object is selected, only the latitude value can be altered and the images change accordingly.

When an object is selected, the latitude value and the declination value of the object can be altered. As either value changes, the calculation of the meridinal altitude for the object is displayed at the right; simultaneously, the images change accordingly.

The user can also display the range of declination values for the Moon, Sun, and a planet.

Declination Ranges Simulator
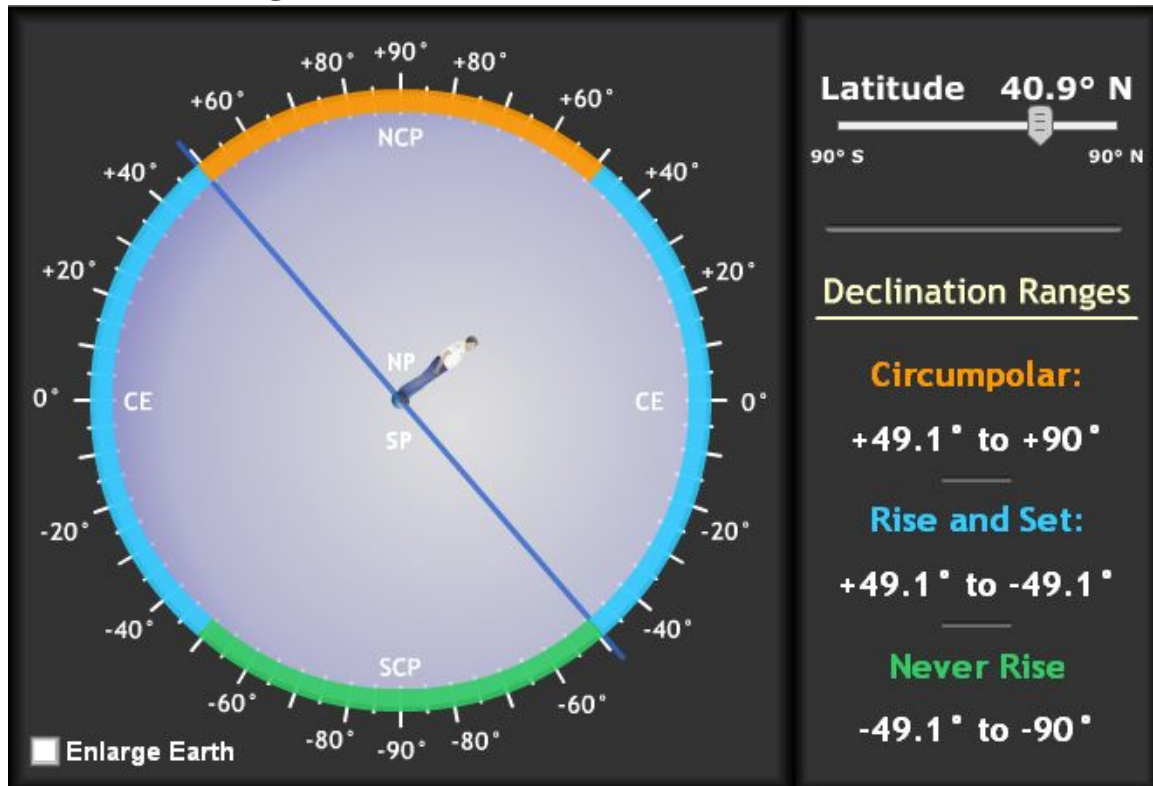
Main Purpose:
This simulator allows the user to determine the declination ranges for circumpolar stars, rise and set stars, and never rise star for any location on the Earth.

Image:
The image displays a person standing on the surface of the Earth at a selected latitude with their local horizon extended outwards to a celestial sphere. The celestial sphere denotes declination values, the celestial equator, the north and south celestial poles, and color-coded declination ranges for circumpolar, rise and set, and never rise stars. On the right, the numerical declination ranges are also displayed.

Controls:
As the latitude is altered, the image and numeric declination ranges for the circumpolar, rise and set, and never rise stars change accordingly.

The user can also enlarge the image of the Earth by clicking the box in the bottom left.

Ecliptic Simulator
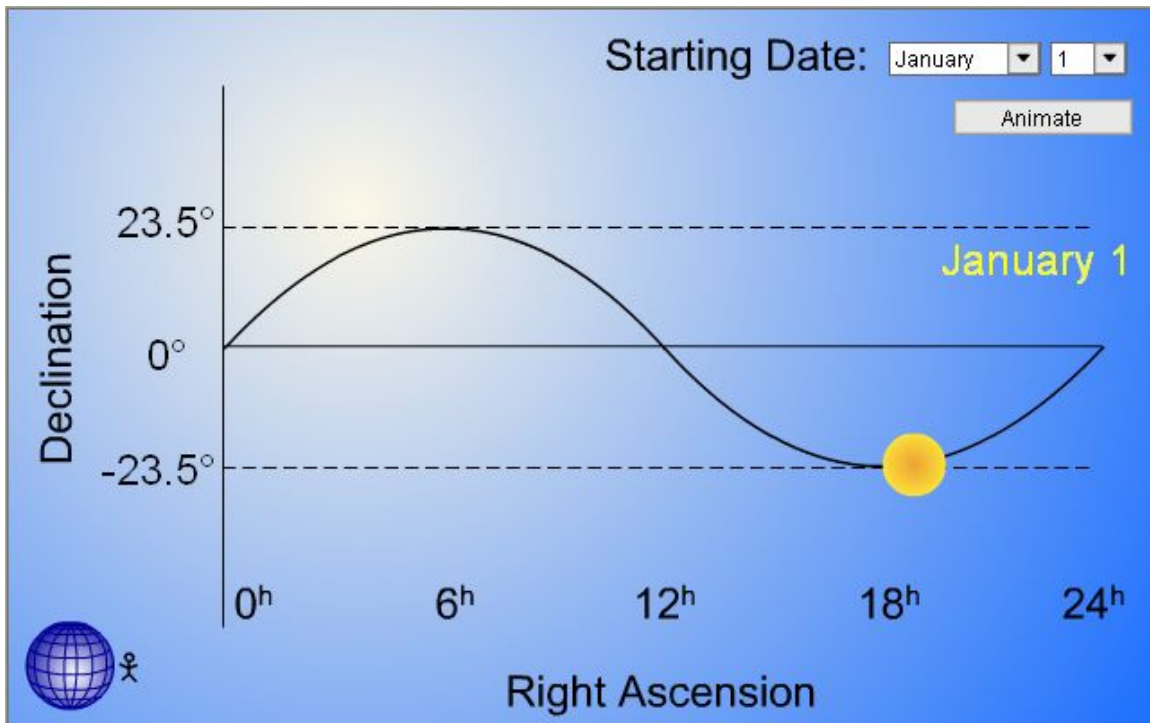
Main Purpose:
This simulator allows the user to observe the apparent motion of the Sun along the ecliptic, starting at a selected date.

Image:
The image displays a graph of Declination versus Right Ascension. The curved line is the ecliptic and the Sun is initially displayed somewhere on the ecliptic depending upon the starting date selected. The date corresponding to the Sun's position on the ecliptic is displayed in yellow at the middle right.

Controls:
At the upper right, the started date can be selected, and the image changes accordingly. If the animate button is clicked, the Sun will begin to move along the ecliptic and the date corresponding to the Sun's position on the ecliptic changes accordingly. The user may then click the stop button to halt the motion of the Sun.

The user can also change the look of the image depending upon if the motion is viewed from inside the celestial sphere or outside the celestial sphere. This is done by clicking the globe and person in the lower left.

Union Seasons Demonstrator
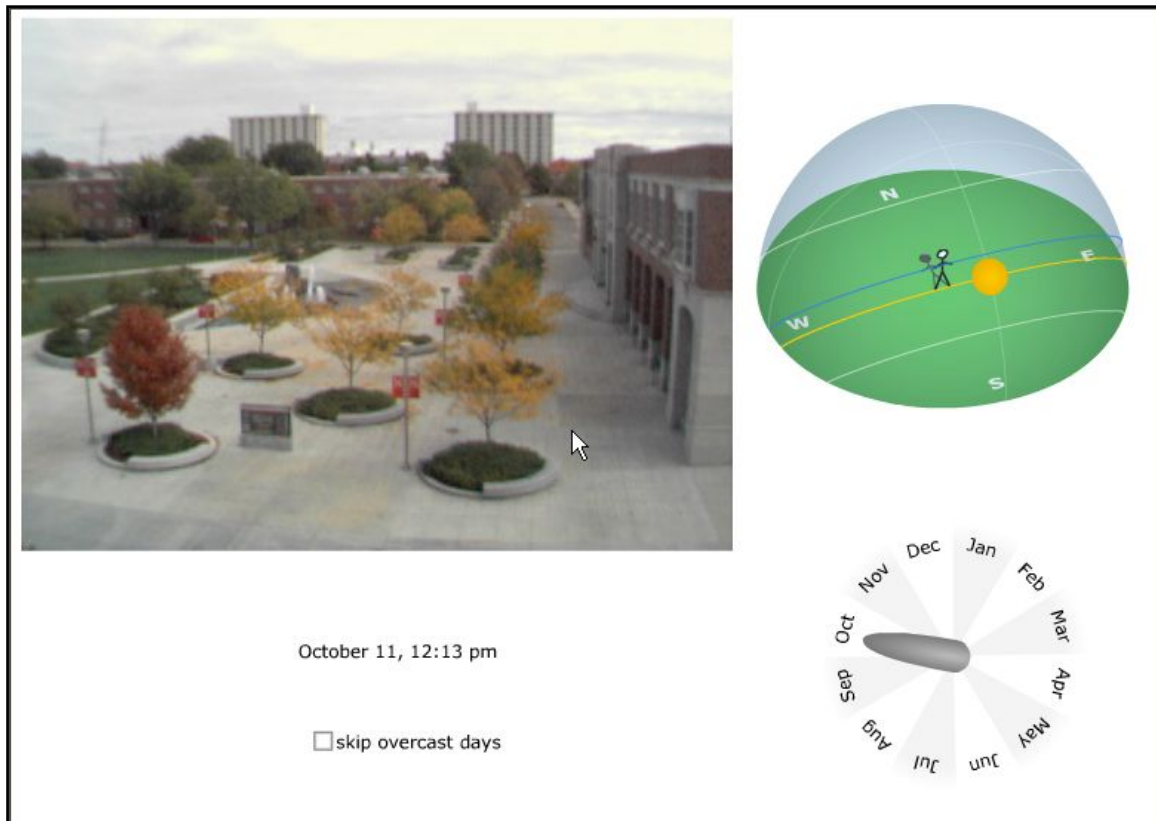
Main Purpose:
This demonstrator allows the user to see the effects of the Sun's apparent annual motion in the sky.

Images:
The image on the left is a picture of the University of Nebraska – Lincoln's student union plaza taken from a camera facing east. The exact date and time the picture was taken is just below the picture.

The image on the right is a local horizon system for the location of the student union plaza on the Earth, which is approximately 41° N latitude. This image displays the local cardinal directions, celestial equator (in blue), the maximum and minimum declinations the Sun will achieve throughout the year (the white lines parallel to the celestial equator), and the local meridian. The image also displays the location of the Sun that corresponds with the picture of the student union plaza.

Controls:
At the bottom right, the user can adjust the time of year and both images will change accordingly.

The user can also skip any pictures of overcast days by clicking the box at the bottom.

Azimuth / Altitude Demonstrator
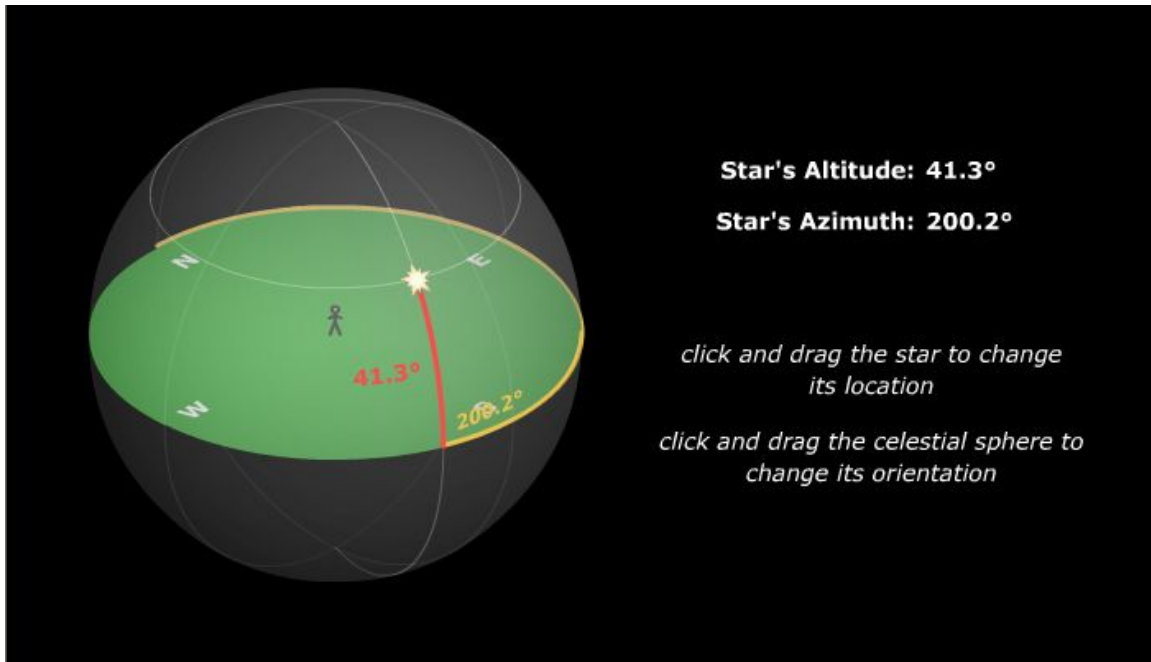
Main Purpose:
This demonstrator allows the user view altitude and azimuth coordinates for a star on a local horizon system display.

Image:
The image displays a local horizon system with the local cardinal directions denoted. A star is also displayed with its azimuth coordinate shown with a yellow line (also numerically in yellow) and its altitude coordinate shown with a red line (also numerically in red). The star's altitude and azimuth values are also shown at the upper right.

Controls:
As stated at the bottom right, the user can alter the location of the star and the image and values of the altitude and azimuth will change accordingly.

The user can also click and drag on the celestial sphere to change its orientation.

Obliquity Simulator
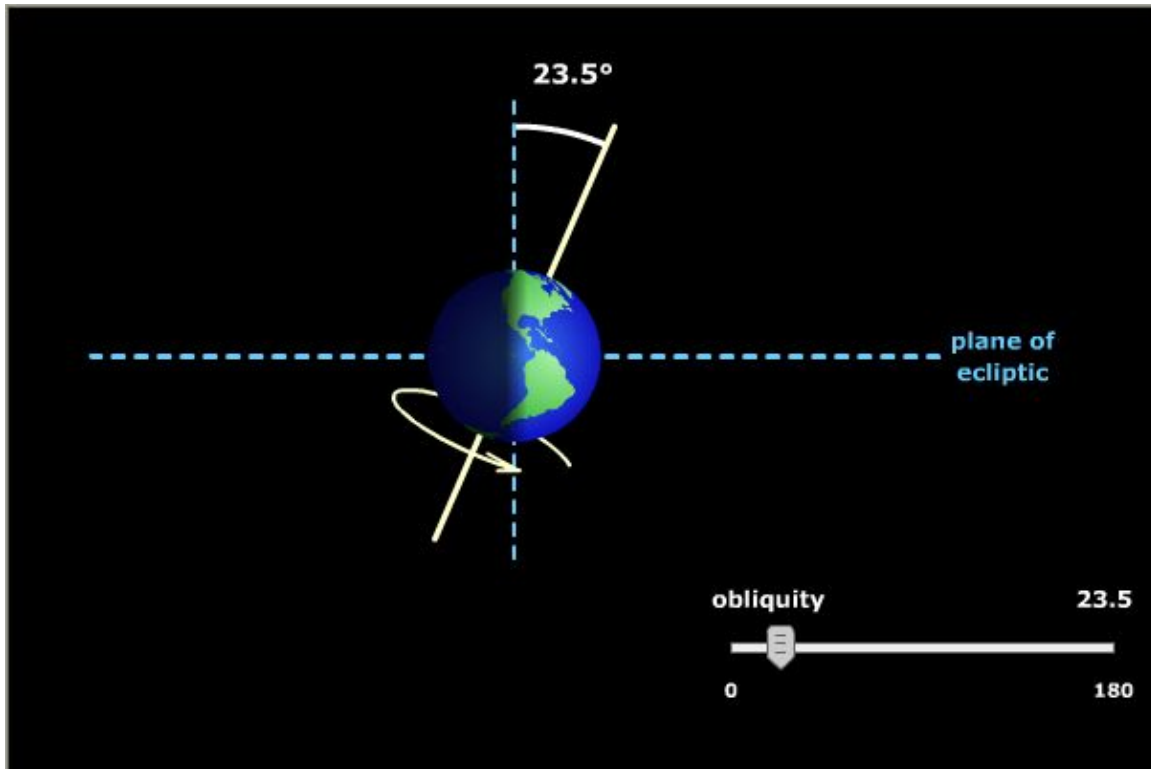
Main Purpose:
This simulator allows the user to view the Earth as it possesses a selected obliquity angle.

Image:
The image displays the Earth with its axis of rotation passing through the north and south poles. The rotation of Earth is denoted with the curved arrow. The plane of ecliptic and a reference line perpendicular to the plane of ecliptic are both shown as dashed blue lines. A current obliquity value is shown between the axis of rotation and the line perpendicular to the plane of the ecliptic.

Controls:
At the lower right, the obliquity value can be selected and the image changes accordingly.

Longitude / Latitude Demonstrator
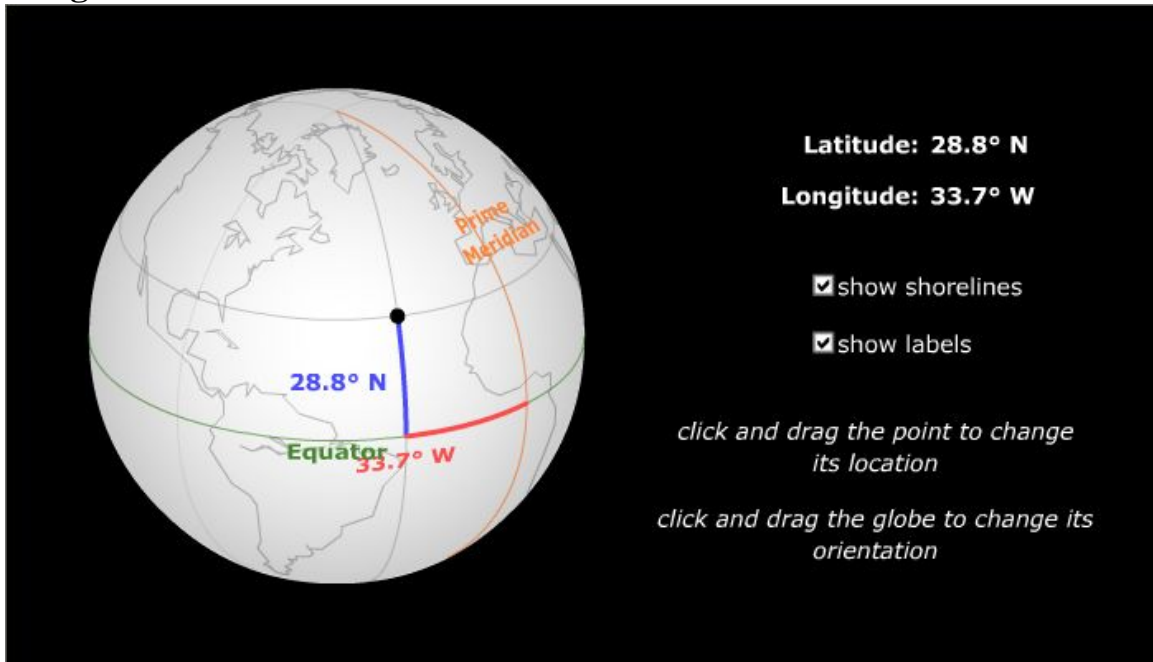
Main Purpose:
This demonstrator allows the user view latitude and longitude coordinates for a location on the surface of the Earth.

Image:
The image displays the Earth with shorelines and the equator and prime meridian labeled. A location is also displayed with its longitude coordinate shown with a red line (also numerically in red) and its latitude coordinate shown with a blue line (also numerically in blue). The location's latitude and longitude values are also shown at the upper right.

Controls:
As stated at the bottom right, the user can alter the location on the surface of the Earth and the image and values of the latitude and longitude will change accordingly.

The user can also click and drag on the celestial sphere is change its orientation, can turn on and off the shorelines, and can turn on and off the labels for the equator and prime meridian.

Right Ascension / Declination Demonstrator
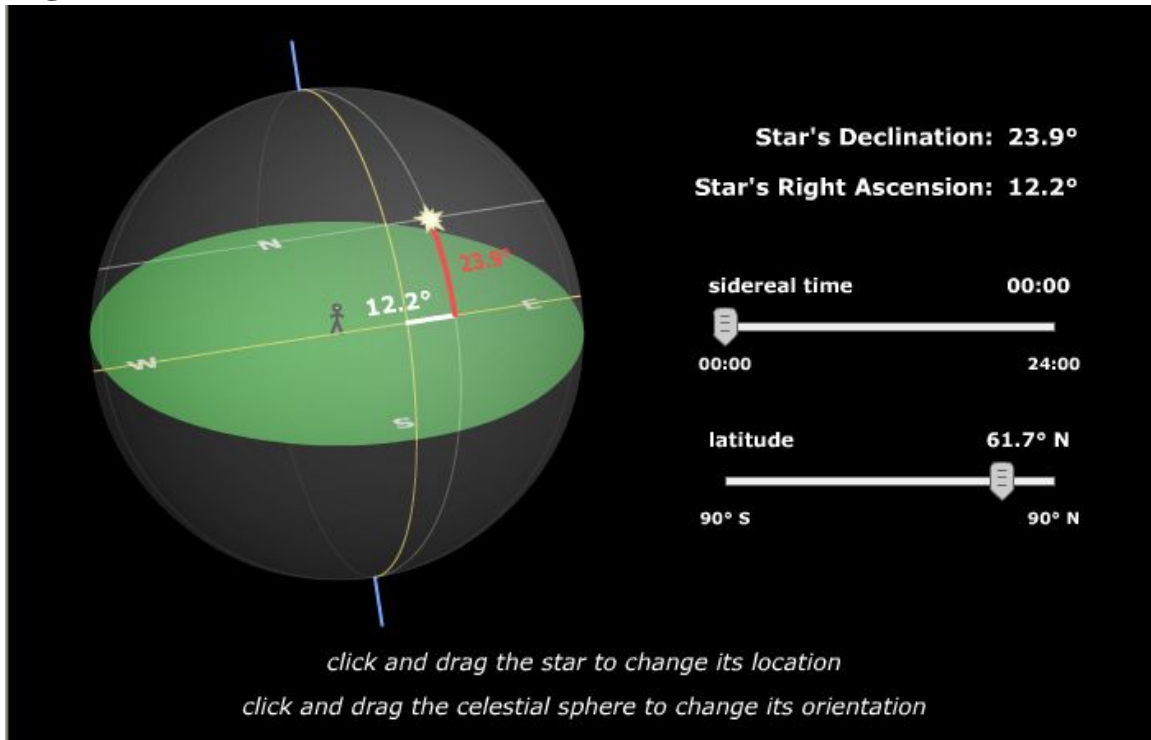
Star's Declination: 23.9°

Star's Right Ascension: 12.2°

sidereal time   00:00

00:00   24:00

latitude   61.7° N

90° S   90° N

click and drag the star to change its location

click and drag the celestial sphere to change its orientation

Main Purpose:
This demonstrator allows the user to view Declination (Dec) and Right Ascension (RA) coordinates for a star located on the celestial sphere.

Secondary Purpose:
This demonstrator allows the user to view how a star with a selected set of Dec and RA coordinates appears from any location on the Earth.

Image:
The image displays a local horizon system for a selected latitude value. This is surrounded by the celestial sphere. The north and south celestial poles are shown with the blue lines. The celestial equator and the RA zero hour circle (whose intersection with the celestial equator marks the location of vernal equinox) are shown with yellow lines. A star is also displayed with its Dec coordinate shown with a red line (also numerically in red) and its RA coordinate shown with a white line (also numerically in white). The star's Dec and RA values are also shown at the upper right.

Controls:
As stated at the bottom, the user can alter the location of the star and the image and values of the Dec and RA will change accordingly.

The user can click and drag the celestial sphere to change its orientation.

At the middle right, the user can also alter the latitude value and sidereal time and the image will change accordingly.

Simplified Right Ascension / Declination Demonstrator

Main Purpose:
This demonstrator allows the user to view Declination (Dec) and Right Ascension (RA) coordinates for a star located on the celestial sphere.
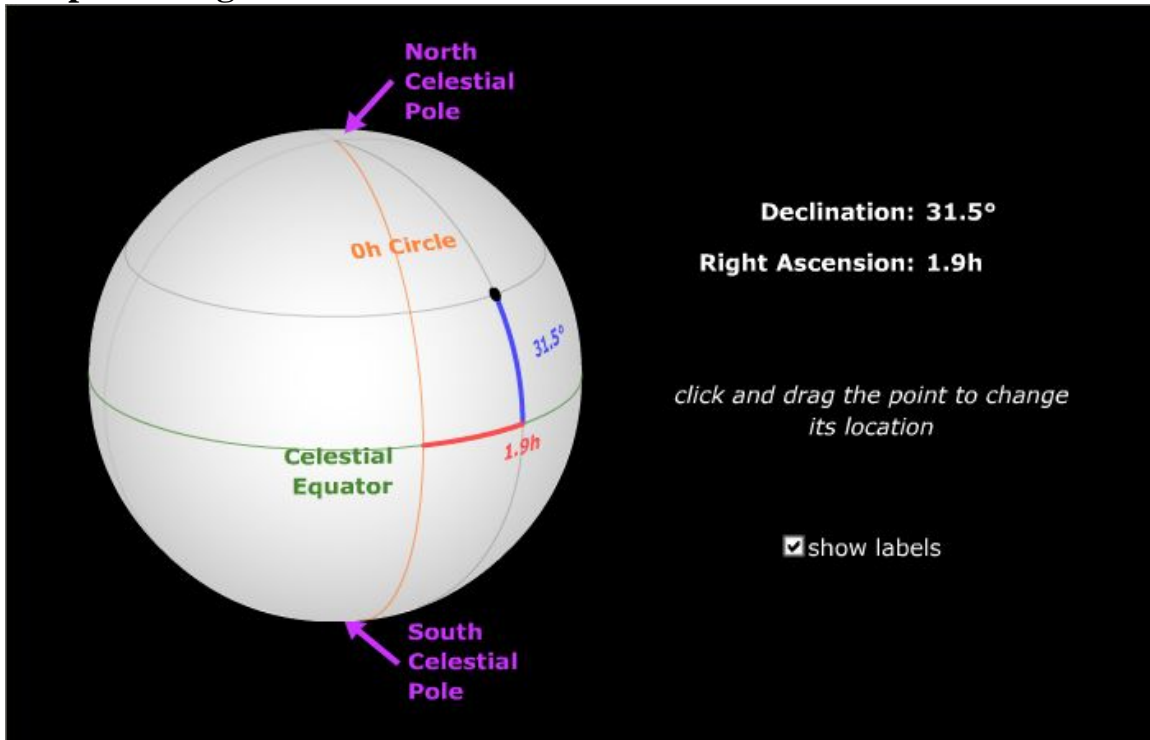
Image:
The image displays a celestial sphere. The celestial equator, the RA zero hour circle (whose intersection with the celestial equator marks the location of vernal equinox), and the north and south celestial poles are labeled. A location on the celestial sphere is also displayed with its Dec coordinate shown with a blue line (also numerically in blue) and its RA coordinate shown with a red line (also numerically in red). The star's Dec and RA values are also shown at the upper right.

Controls:
As stated at the middle right, the user can alter the location on the celestial sphere and the image and values of the Dec and RA will change accordingly.

The user can click and drag the celestial sphere to change its orientation, and can turn on and off the labels for the celestial equator, the RA zero hour circle, and the north and south celestial poles.

Paths of the Sun Demonstator
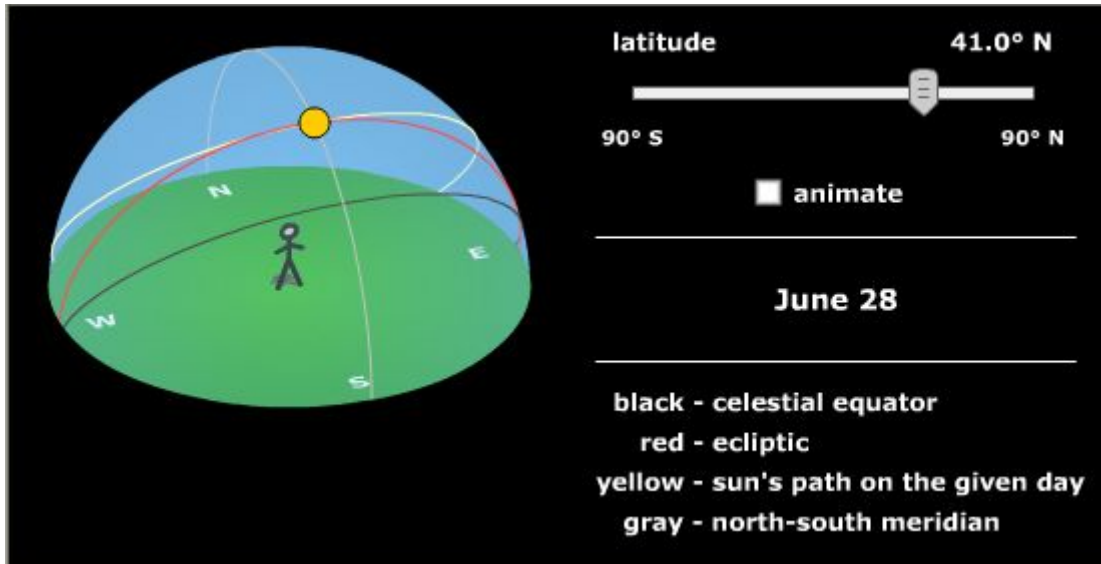
Main Purpose:
This demonstrator allows to user to view the daily and annual motions of the Sun in the sky for any latitude on the Earth.

Image:
The image displays a local horizon system for a selected latitude value. The local cardinal directions are labeled. As noted in the bottom right, the celestial equator (in black), the ecliptic (in red), the sun's path on the given day (in yellow) and the local meridian (in gray) are labeled. The Sun is also shown at an appropriate declination above or below the celestial equator depending upon the given day (displayed at the middle right).

Controls:
At the upper left, the user can alter the latitude value and the image will change accordingly.

The user can click the animate button, which will steadily change the given day while simultaneously changing the image accordingly. The user can stop the animation by re-clicking the animate button.

The user can also click and drag on the image to change its orientation.

Draggable Sun Demonstrator

Main Purpose:
This demonstrator allows to user to view the daily and annual motions of the Sun in the sky for any latitude on the Earth.

Image:
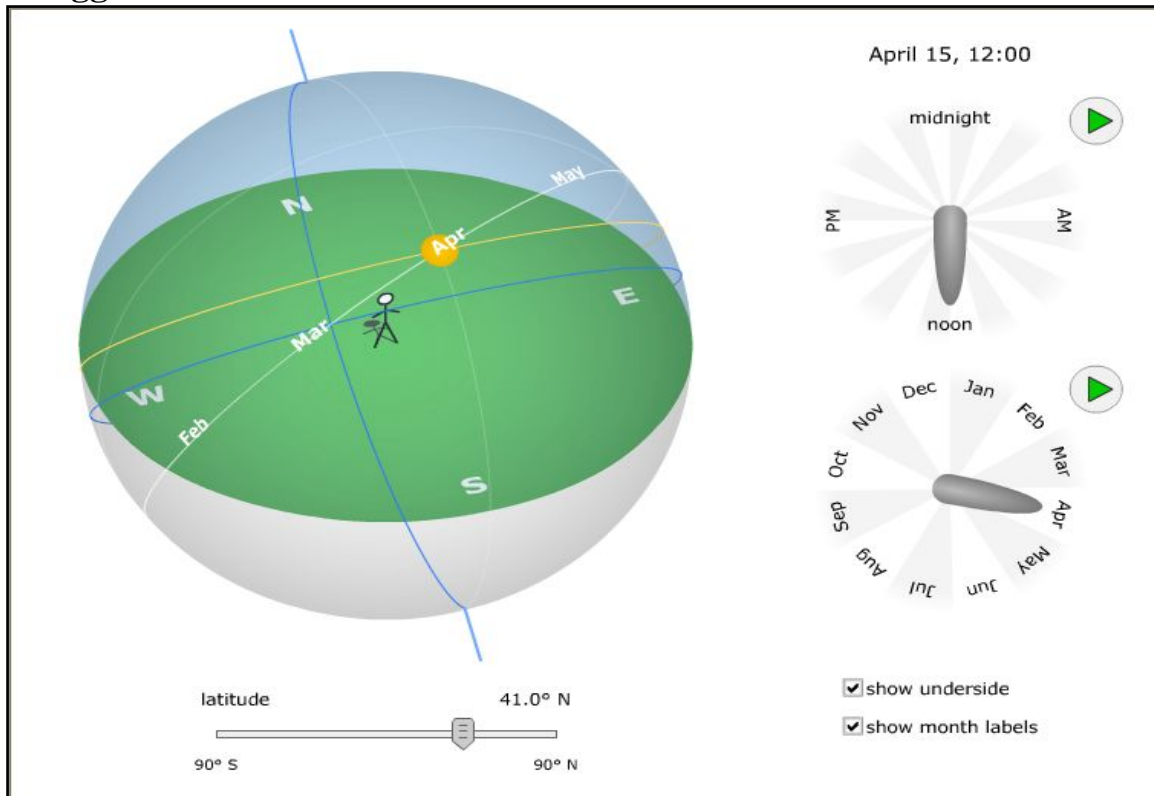The image displays a local horizon system for a selected latitude value. The local cardinal directions are labeled. The celestial equator, the Right Ascension zero hour circle (whose intersection with the celestial equator marks the location of vernal equinox), and the north and south celestial poles are denoted with blue lines. The ecliptic is the white line with the months labeled, and the sun's path on the given day is the yellow line. The Sun is also shown at an appropriate declination above or below the celestial equator depending upon the given day and time (displayed at the upper right).

Controls:
At the bottom, the user can alter the latitude value and the image will change accordingly.

At the upper right, the user can click and drag the dial to a specific time of day and the image will change accordingly, as will the day and time display. This can also be accomplished by clicking and dragging the Sun itself. The user can also just click the green "play" button to the upper right of this dial. This will steadily change the time by fractions of hours while simultaneously changing the image accordingly. The user can stop the animation by now clicking the red "stop" button.

At the middle right, the user can click and drag the dial to a specific month of the year and the image will change accordingly, as will the day and time display. The user can also just click the green "play" button to the upper right of this dial. This will steadily change the time by fractions of months while simultaneously changing the image accordingly. The user can stop the animation by now clicking the red "stop" button.

The user can click and drag on the image to change its orientation, and can turn on and off the underside of the celestial sphere and the month labels on the ecliptic.

Sun's Rays Simulator
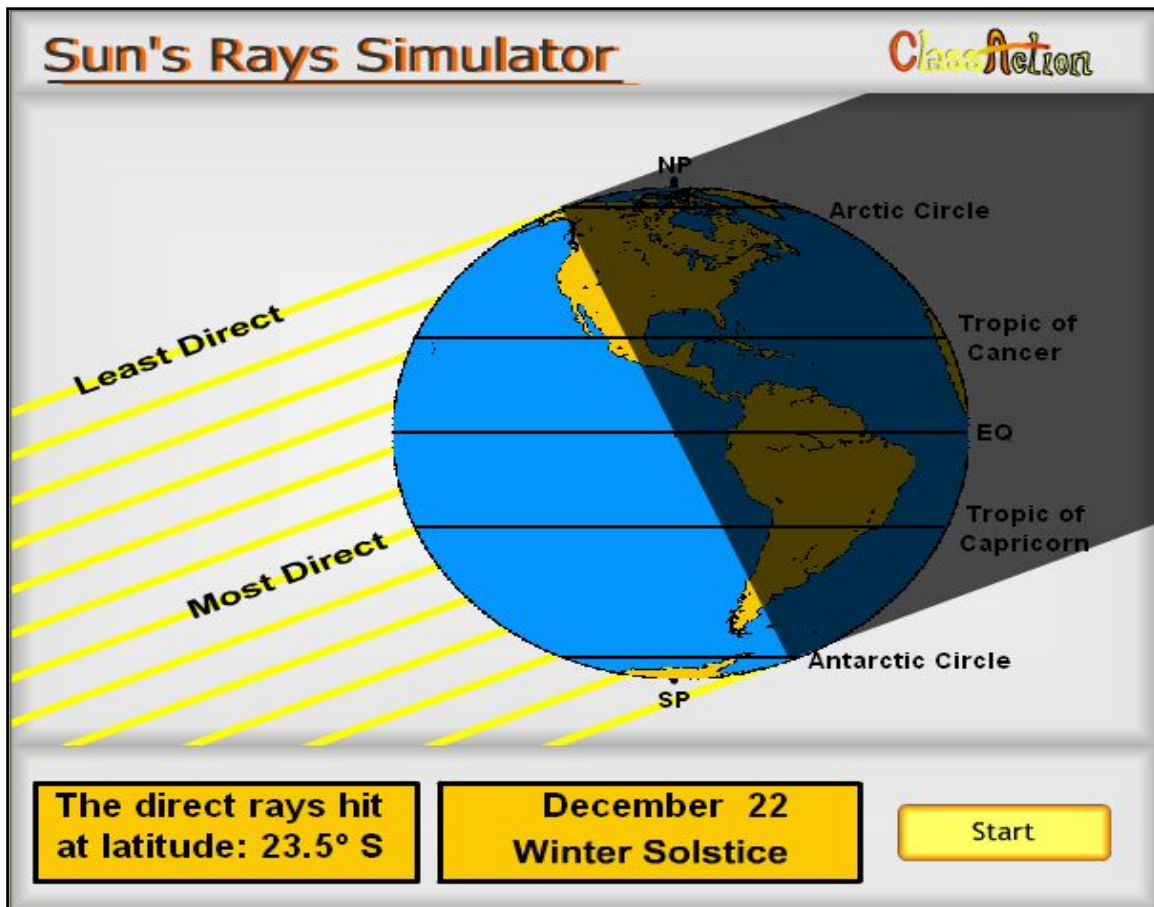
Main Purpose:
This simulator allows the user to view how the Sun's rays strike the Earth throughout the course of a year.

Image:
The image displays the Earth being struck by the Sun's rays at a certain angle. The Sun's rays are shown as parallel yellow lines, with the least direct and most direct sunlight striking the Earth labeled. The side of the Earth not struck by sunlight is shown in shadow. On the Earth itself, the north pole, the Artic circle, the Tropic of Cancer, the equator, the Tropic of Capricorn, the Antarctic Circle, and the south pole are all labeled. At the bottom, the latitude on the Earth that is receiving the most direct rays of sunlight is shown, as well as the day of the year that corresponds to the image.

Controls:
At the lower right, the user can click the start button. This will steadily change the day of the year while simultaneously changing the image and the latitude hit by direct sunlight accordingly. As the days of the year approach a given equinox or solstice, this will be shown underneath the date itself (as with the image above). The user can halt the animation by clicking the stop button at any time.

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

Declination: An image of the celestial sphere with an emphasis on the coordinate of Declination.

Right Ascension: An image of the celestial sphere with an emphasis on the coordinate of Right Ascension.

Celestial Sphere: An image of the celestial sphere with the apparent motion of the sphere and a few constellations shown.

North Celestial Pole: An overexposed photograph of the night sky showing circular star trails of some circumpolar stars.

Precession: a) An image of the Earth's precession being compared to the that of a spinning top. b) An image of the north celestial pole's path of precession from 2000 B.C. to 24,000 A.D.

Terrestrial Coordinates: An image of the celestial sphere that compares the terrestrial coordinates of latitude and longitude with the celestial equatorial coordinates of Declination and Right Ascension.

Time Zones: A map of the world displaying the International Date Line, the prime meridian, and the all the time zones.

Ecliptic: An image of the celestial sphere displaying the ecliptic and the locations of the summer and winters solstices.

Seasons: An image of the tilted Earth's in its orbit around the Sun with an emphasis on the orientation of the tilt the days of the winter and summer solstice and vernal and autumnal equinox – intended to help explain the cause for the seasons.

Solar Day: A image of the Earth in its orbit around the Sun with an emphasis on the orientation of the Earth with respect to the Sun after a 24 hour time period – intended to help understand the definition of a solar day.

Solar Motion: Two images that compare the actual motion of the Earth around the Sun to the apparent motion of the Sun on the celestial sphere.

Orion I: a) A photograph of the constellation Orion. B) A graphic representation of Orion drawn over the stars of the constellation.

Orion II: An image of the stars of Orion, but shown to emphasis that not all the stars are located the same distance from the Earth.

Seasonal Constellations: a) An image of the constellations near the southern horizon during the summer season. b) An image of the constellations near the southern horizon during the winter season.

Zodiac: An image of the Earth in its orbit around the Sun and the locations of the constellations of zodiac (a.k.a. the constellations the Sun appears to travel through during the year) beyond Earth's orbit.

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

Terrestrial Coordinates: A primer about the terrestrial coordinates of Latitude and Longitude.

Parallels of Latitude: An image and table on the subject of various special lines of latitude, like the Arctic Circle and the Tropic of Capricorn.

Celestial Equatorial Coordinates: A primer about the celestial equatorial coordinates of Declination and Right Ascension.

Ecliptic: An image and table on the subject of the apparent motion of the Sun on the celestial sphere throughout the year and the Right Ascension and Declination coordinates of the Sun on special days of the year.

Horizon Coordinates: A primer about the local horizon system coordinates of Azimuth and Altitude.

Declination Ranges: An image and table on the subject of the declination ranges for circumpolar stars, never rise stars, and rise & set stars for any latitude on the Earth.

Meridinal Altitude: An image and primer on how to determine the meridinal altitude for any object in the sky, given that object's declination, for any latitude on the Earth.