Earth, Moon, and Sky

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Outline

1) Finding objects on Earth and in the Sky.

2) Determining the source of seasons on Earth.

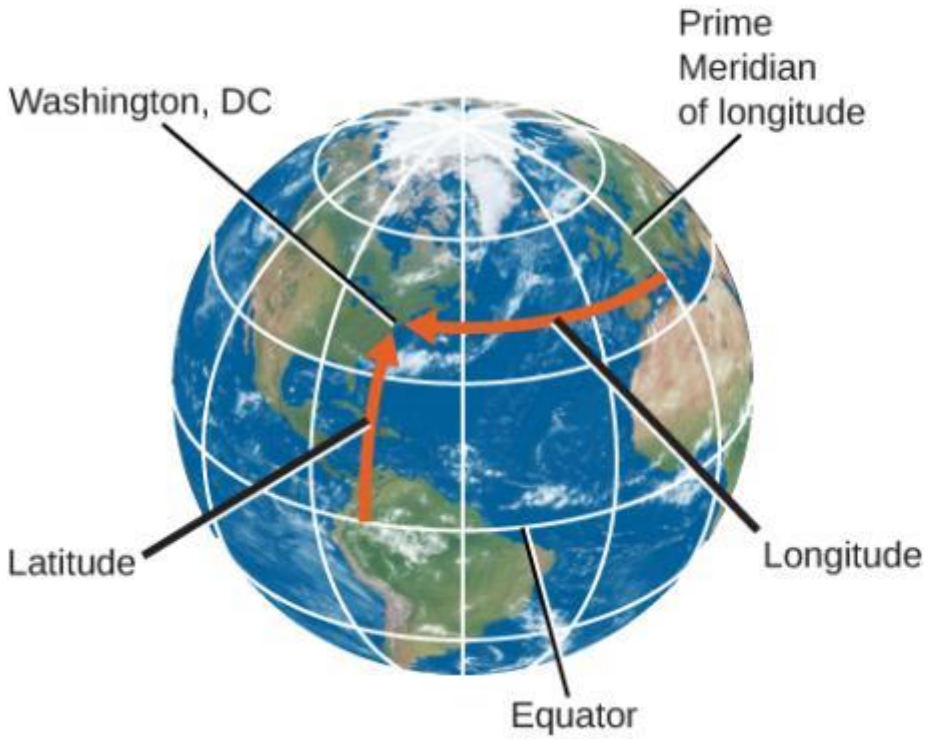
3) Explanation of the phases of the Moon and its motion (rotation/revolution).

4) What are tides and how do they affect the Earth?

5) Categorizing the types of eclipses and determining the causes/timing of eclipses.

Lecture Section 1: Finding objects

Locations on Earth

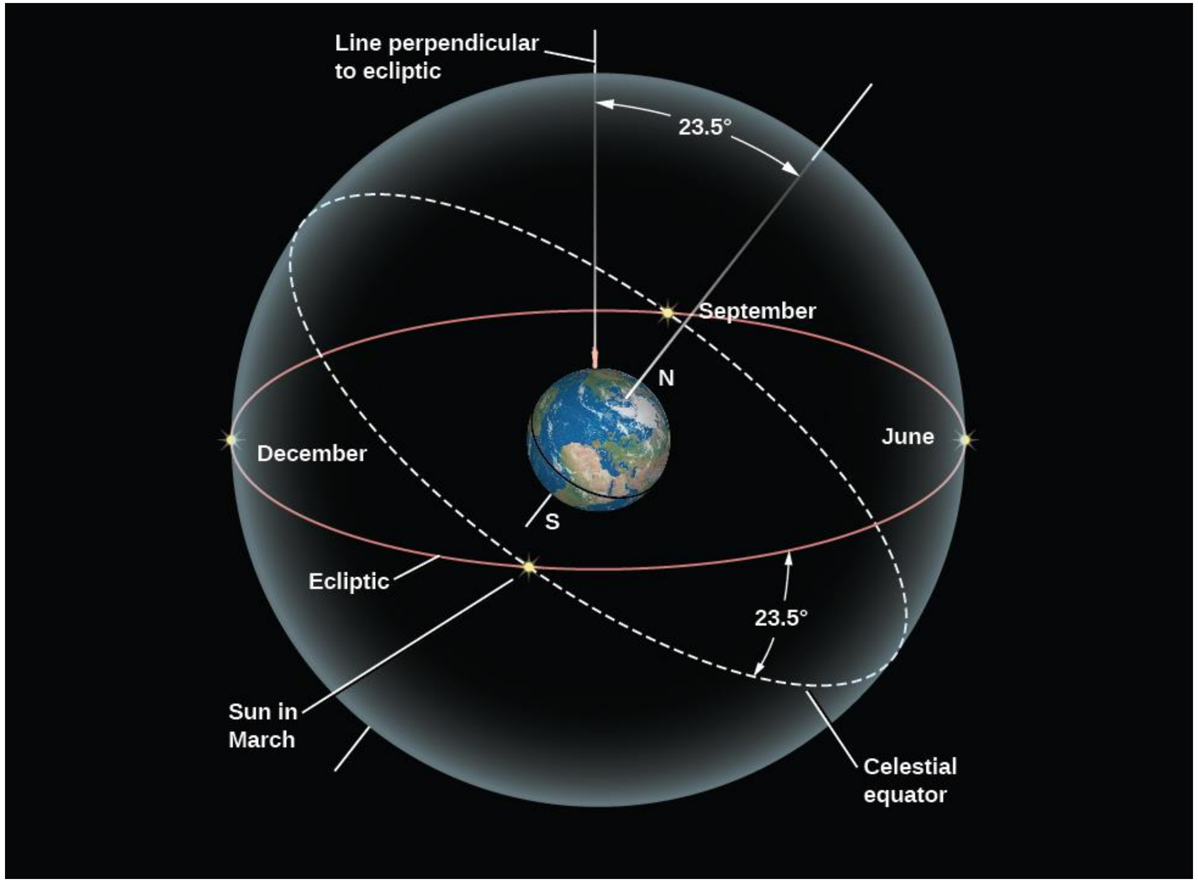


Latitude and Longitude of Washington, DC. We use latitude and longitude to find cities like Washington, DC, on a globe. Latitude is the number of degrees north or south of the equator, and longitude is the number of degrees east or west of the Prime Meridian. Washington, DC's coordinates are 38° N and 77° W.

Locations on Earth

Royal Observatory in Greenwich, England. At the internationally agreed-upon zero point of longitude at the Royal Observatory Greenwich, tourists can stand and straddle the exact line where longitude "begins."(credit left: modification of work by "pdbreen"/Flickr; credit right: modification of work by Ben Sutherland)

Locations in Space



Right Ascension and Declination

Recalling from Chapter 2, we use right ascension and declination to measure angles in the sky. Right ascension runs north to south and measures east (0 hrs) to west (24 hrs), while declination runs east to west and measures north (+90 degrees) to south (-90 degrees).

Earth's Rotation

Foucault's Pendulum. As Earth turns, the plane of oscillation of the Foucault pendulum shifts gradually so that over the course of 12 hours, all the targets in the circle at the edge of the wooden platform are knocked over in sequence. (credit: Manuel M. Vicente)

Lecture Section 2: Seasons on Earth

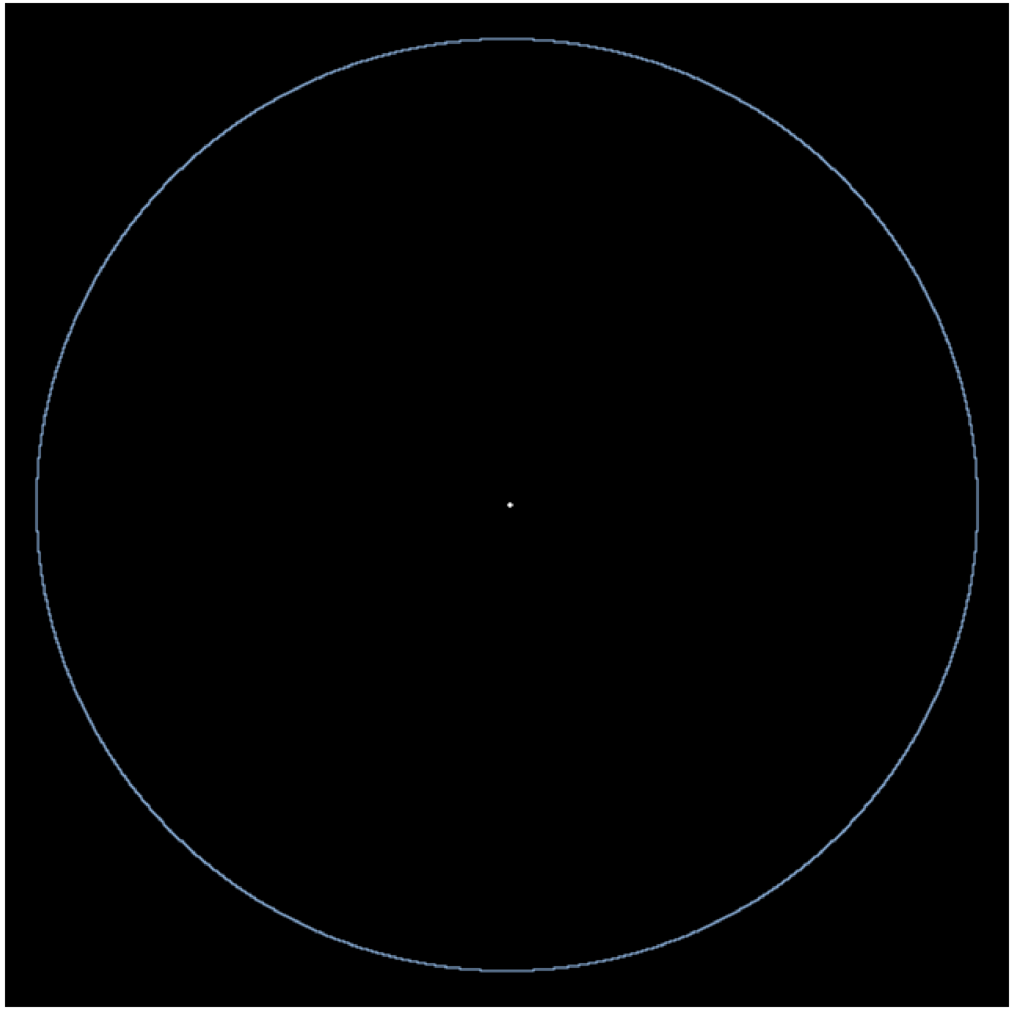
Seasons Misconception: Closer means More

Dealing with misconceptions

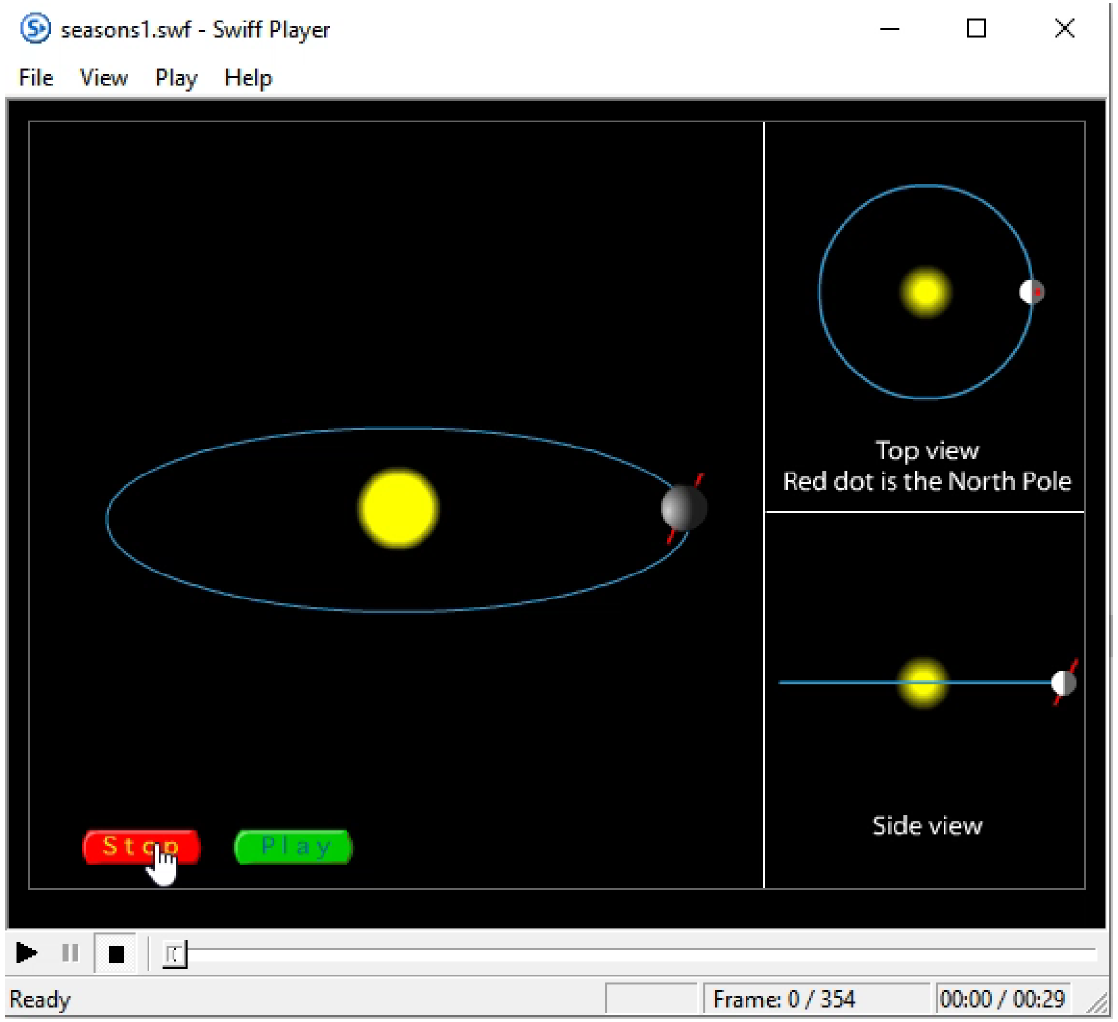
- Heat: The closer you are the hotter it is
- Sound: The closer you get, the louder it is
- Why wouldn't hotter seasons mean the Earth is closer to the Sun?

Seasons Misconception: Closer means More

- Earth and Sun shown at the correct scale.
- Can you tell that this is an elliptical?
- Difference between closest point (perihelion) and farthest (aphelion) is only about 3%.

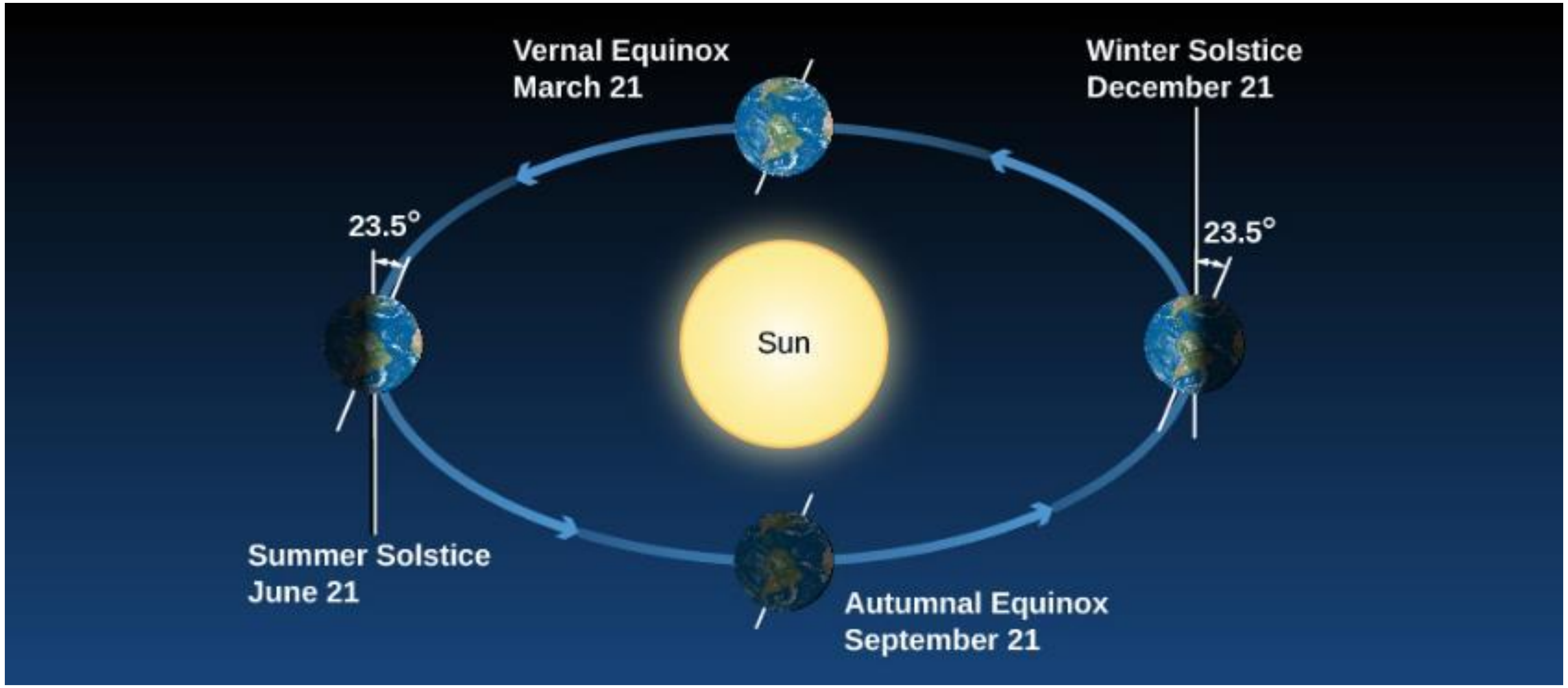


Earth’s Orbit and Axial Tilt



- Video shows the side view, top view, and a tilted view of the Earth in its orbit.
- Shows how the Earth northern pole tilts toward the Sun on Jun. 21st and southern pole toward the Sun on Dec. 21st.

Earth’s Orbit and Axial Tilt

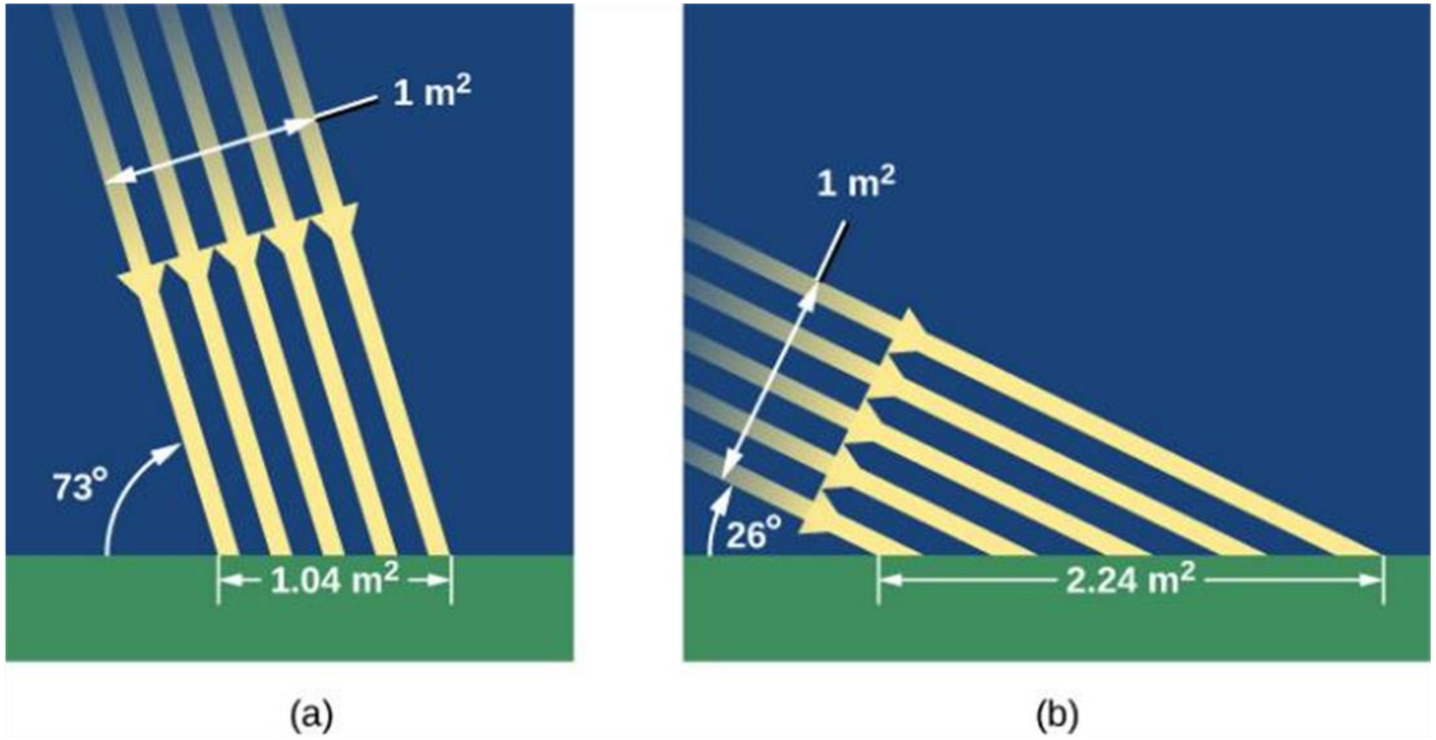


Seasons. We see Earth at different seasons as it circles the Sun. In June, the Northern Hemisphere “leans into” the Sun, and those in the North experience summer and have longer days. In December, during winter in the Northern Hemisphere, the Southern Hemisphere “leans into” the Sun and is illuminated more directly. In spring and autumn, the two hemispheres receive more equal shares of sunlight.

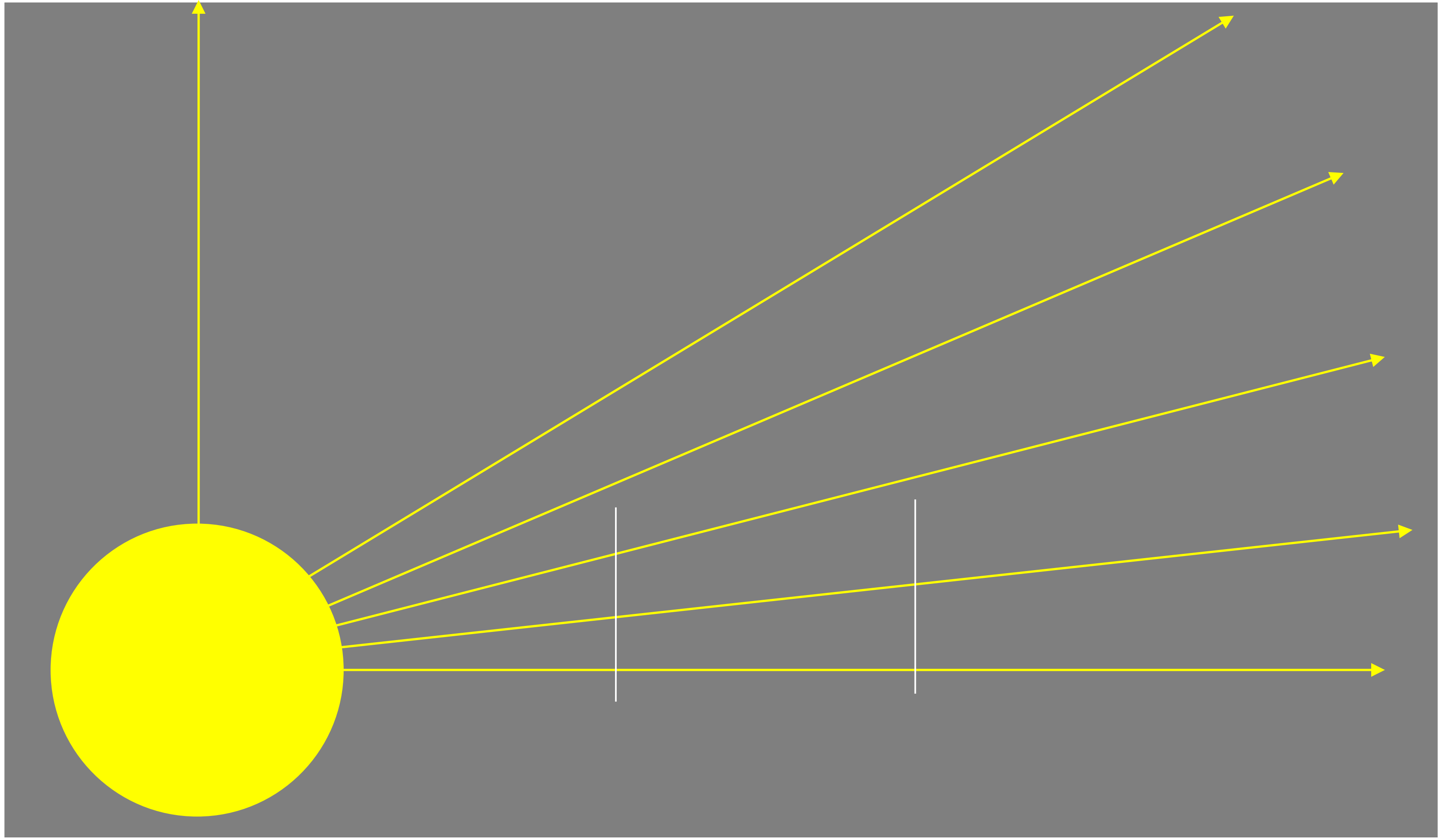
Direct Rays – Example 1

(a) In summer, the Sun appears high in the sky and its rays hit Earth more directly, spreading out less.

(b) In winter, the Sun is low in the sky and its rays spread out over a much wider area, becoming less effective at heating the ground.

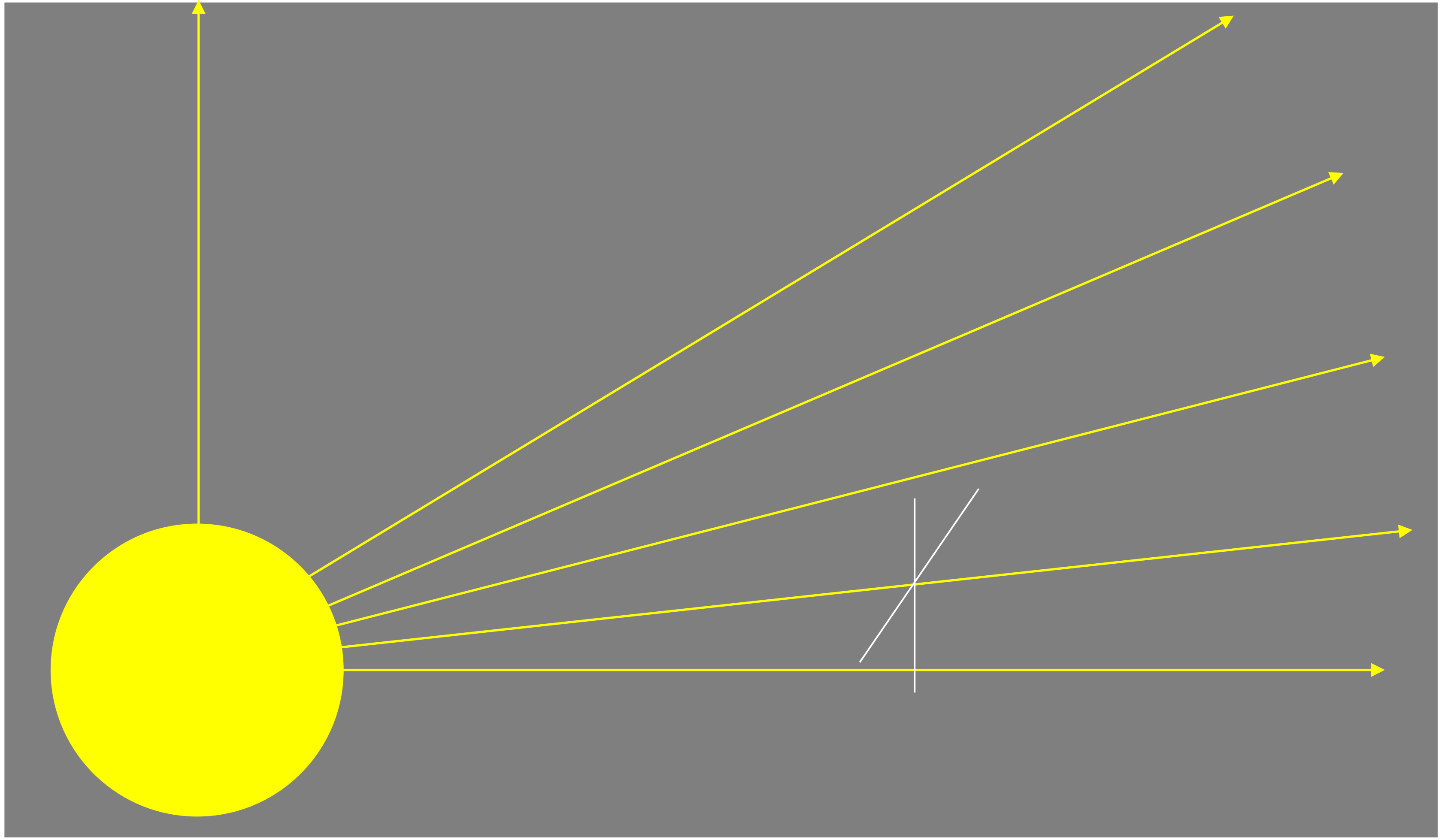


Direct Rays – Example 2



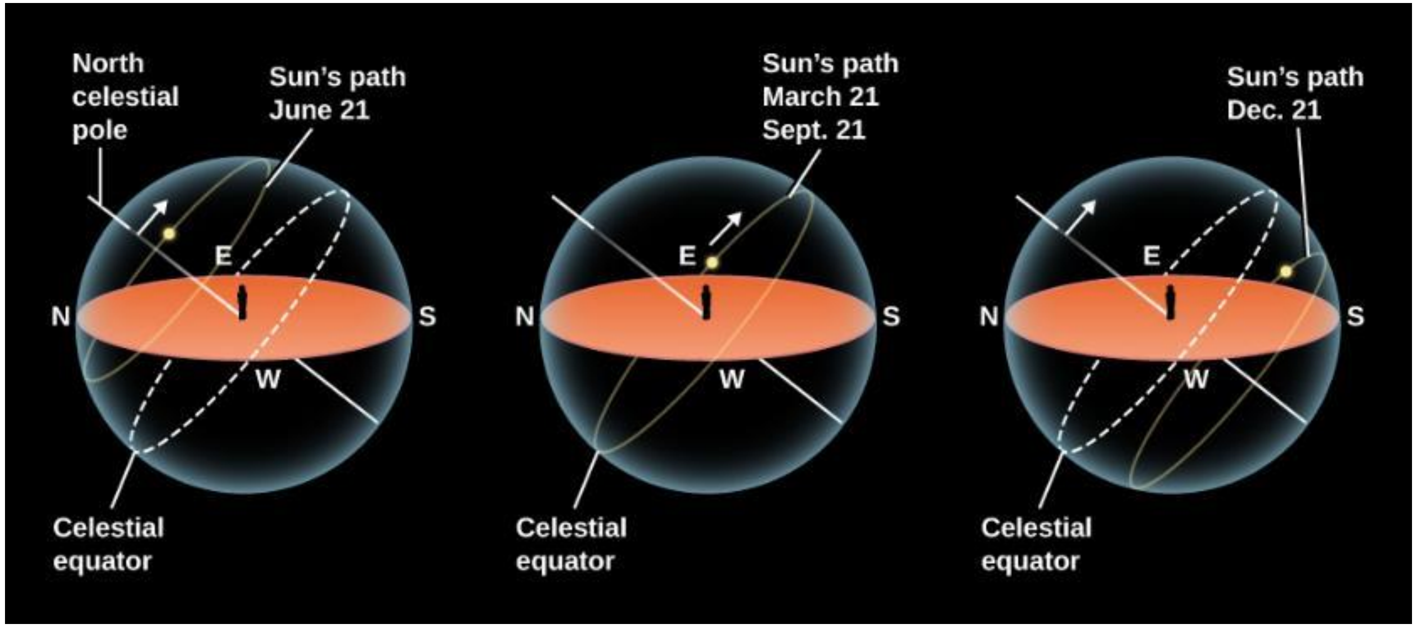
- Cartoon to demonstrate direct rays.
- Distance for the same size line affects how many rays are received.
- Demonstrates the $1/d^2$ law.

Direct Rays – Example 2



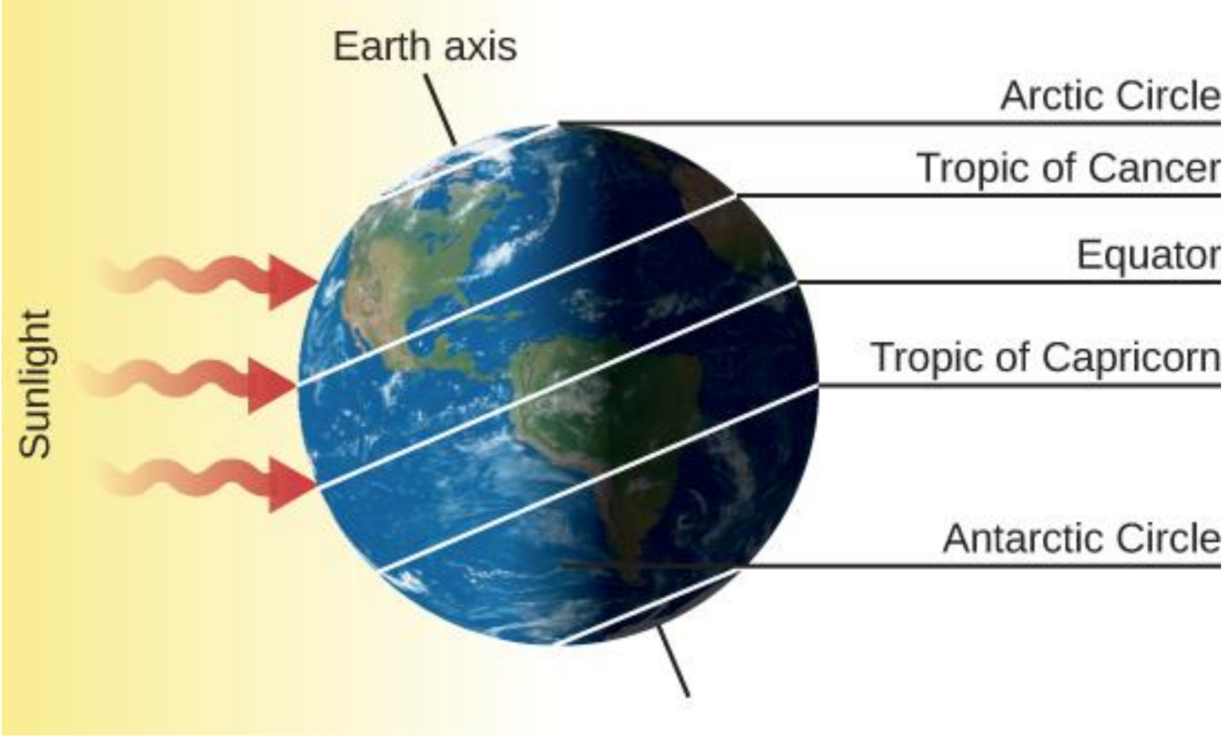
- Cartoon to demonstrate direct rays.
- Angle also affects the number of rays received.
- By angling the line by approximately 30 degrees, it only intersects 1 ray, not 2

Length of the Day



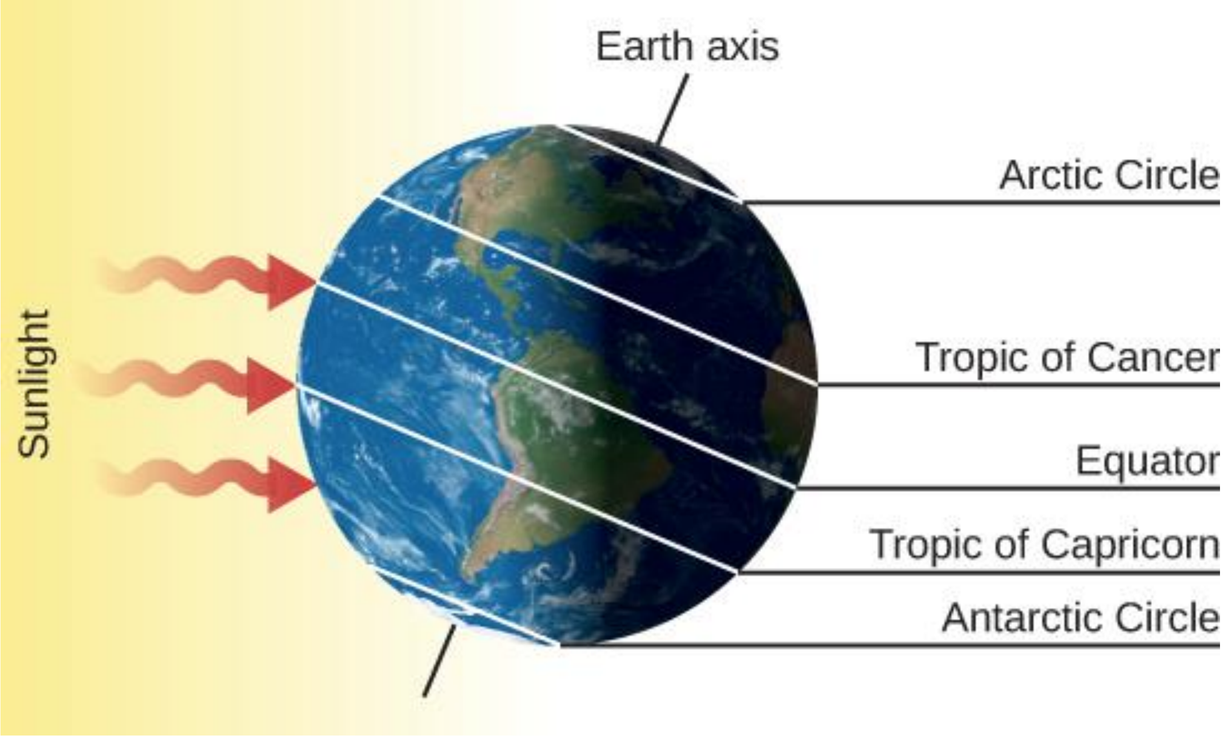
The Sun's Path in the Sky for Different Seasons. On June 21, the Sun rises north of east and sets north of west. For observers in the Northern Hemisphere of Earth, the Sun spends about 15 hours above the horizon in the United States, meaning more hours of daylight. On December 21, the Sun rises south of east and sets south of west. It spends 9 hours above the horizon in the United States, which means fewer hours of daylight and more hours of night in northern lands (and a strong need for people to hold celebrations to cheer themselves up). On March 21 and September 21, the Sun spends equal amounts of time above and below the horizon in both hemispheres.

Length of the Day



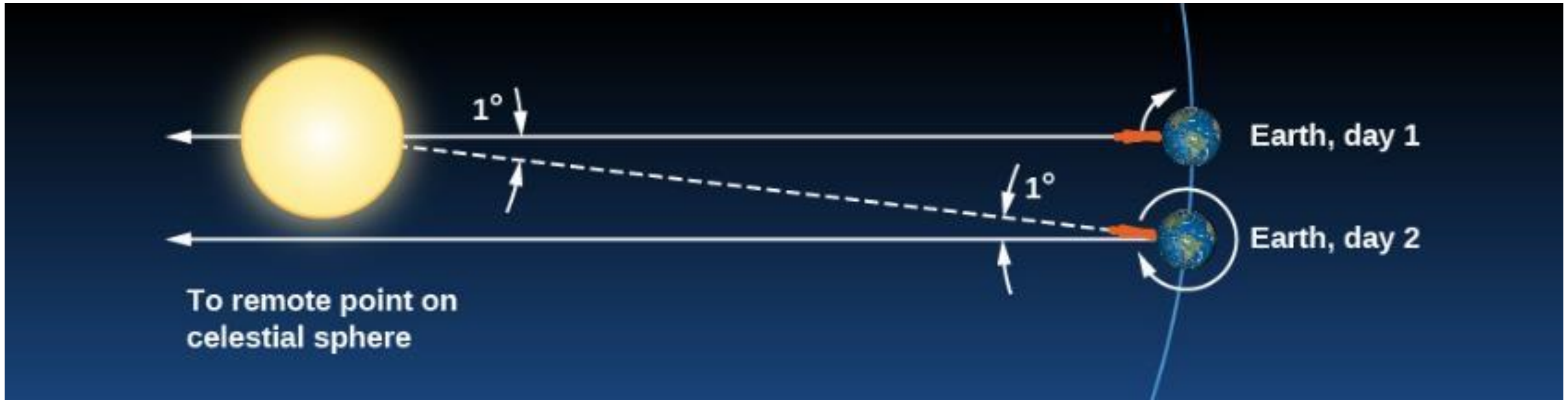
Earth on June 21. This is the date of the summer solstice in the Northern Hemisphere. Note that as Earth turns on its axis (the line connecting the North and South Poles), the North Pole is in constant sunlight while the South Pole is veiled in 24 hours of darkness. The Sun is at the zenith for observers on the Tropic of Cancer.

Length of the Day



Earth on December 21. This is the date of the winter solstice in the Northern Hemisphere. Now the North Pole is in darkness for 24 hours and the South Pole is illuminated. The Sun is at the zenith for observers on the Tropic of Capricorn and thus is low in the sky for the residents of the Northern Hemisphere.

Earth’s Orbit and Spin



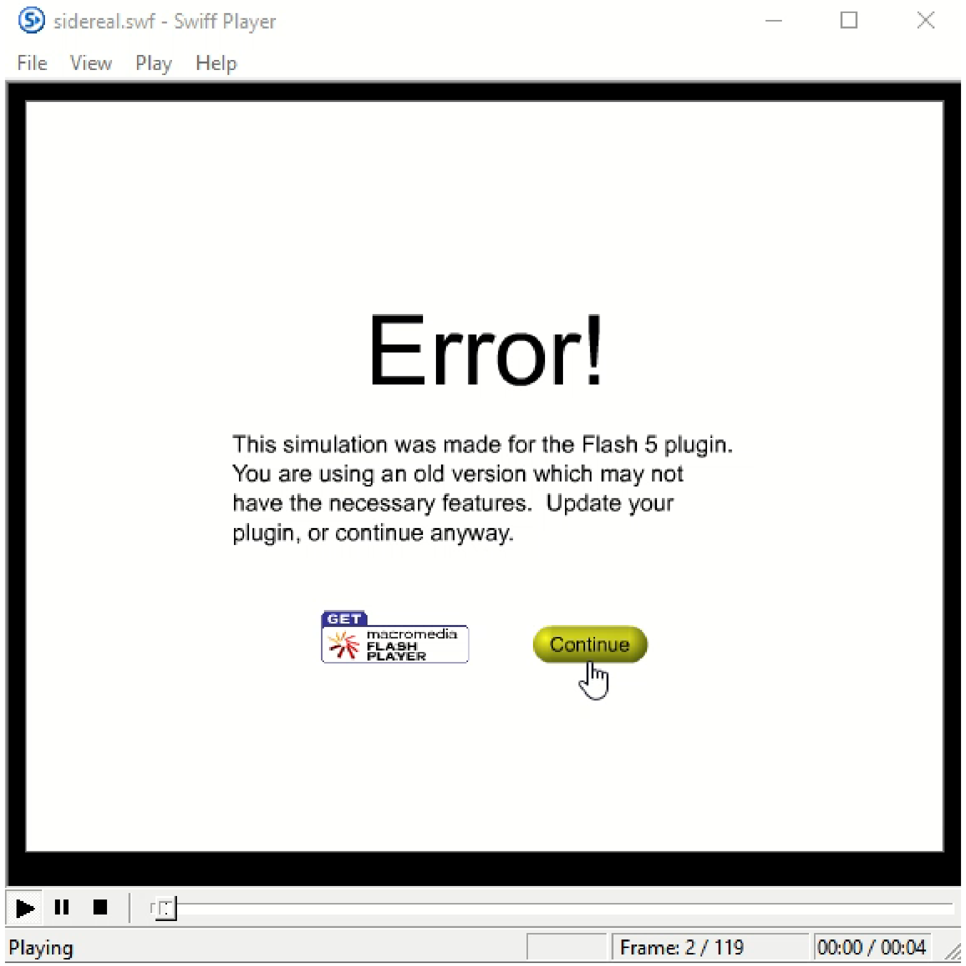
Difference Between a Sidereal Day and a Solar Day. This is a top view, looking down as Earth orbits the Sun. Because Earth moves around the Sun (roughly 1° per day), after one complete rotation of Earth relative to the stars, we do not see the Sun in the same position.

Earth’s Orbit and Spin

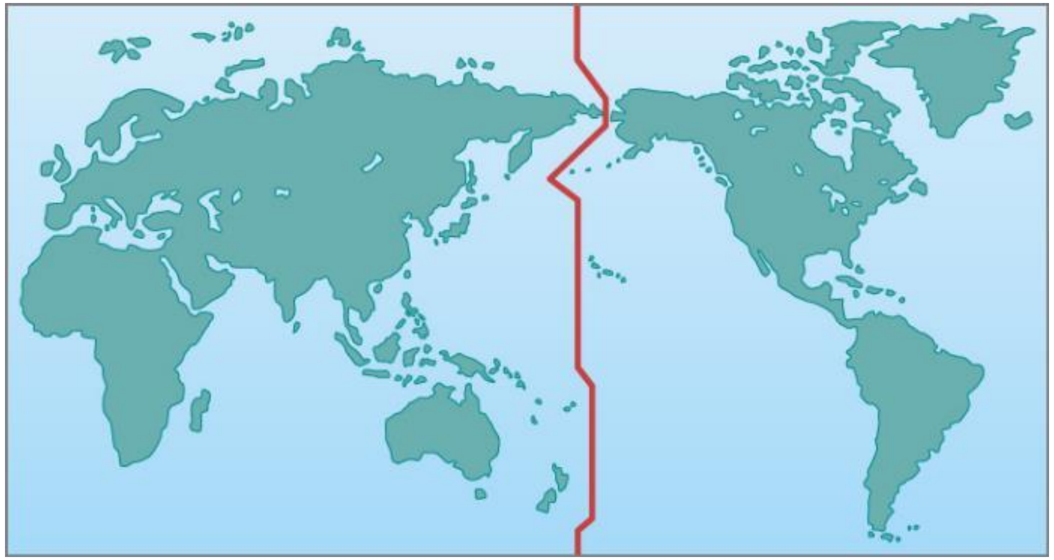
(note: this is no error in the video)

Earth’s orbit and rotation video

- To illustrate the motion of the Earth, the video connects a blue line with a star directly opposite from the Sun (yellow line).
- While not to scale, as the Earth spins, the blue line reconnects with the star before the yellow line connects with the Sun.



Keeping Time



Where the Date Changes. The International Date Line is an arbitrarily drawn line on Earth where the date changes. So that neighbors do not have different days, the line is located where Earth’s surface is mostly water.

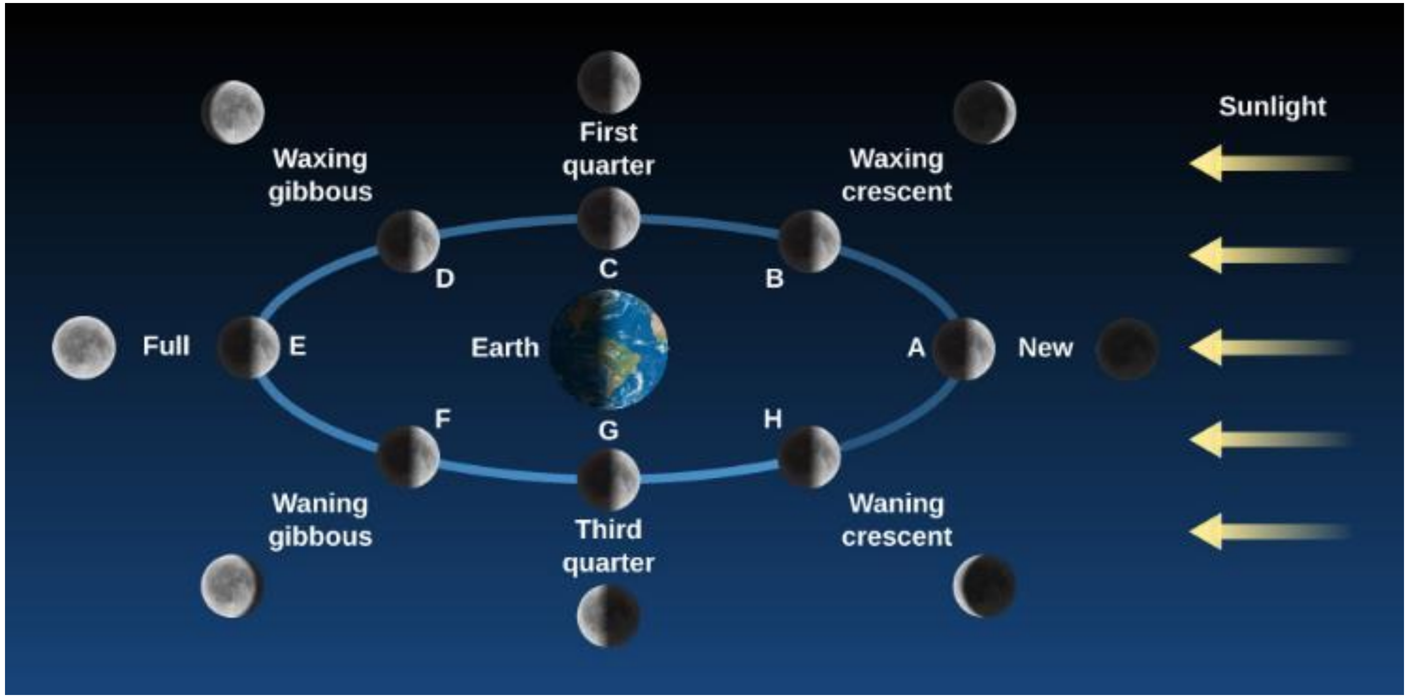
Keeping Time

Stonehenge. The ancient monument known as Stonehenge was used to keep track of the motions of the Sun and Moon. (credit: modification of work by Adriano Aurelio Araujo)

Lecture Section 3: The Moon

Phases of the Moon

Phases of the Moon. The appearance of the Moon changes over the course of a complete monthly cycle. The pictures of the Moon on the white circle show the perspective from space, with the Sun off to the right in a fixed position. The outer images show how the Moon appears to you in the sky from each point in the orbit. Imagine yourself standing on Earth, facing the Moon at each stage. In the position "New," for example, you are facing the Moon from the right side of Earth in the middle of the day. (Note that the distance of the Moon from Earth is not to scale in this diagram: the Moon is roughly 30 Earth-diameters away from us.) (credit: modification of work by NASA)



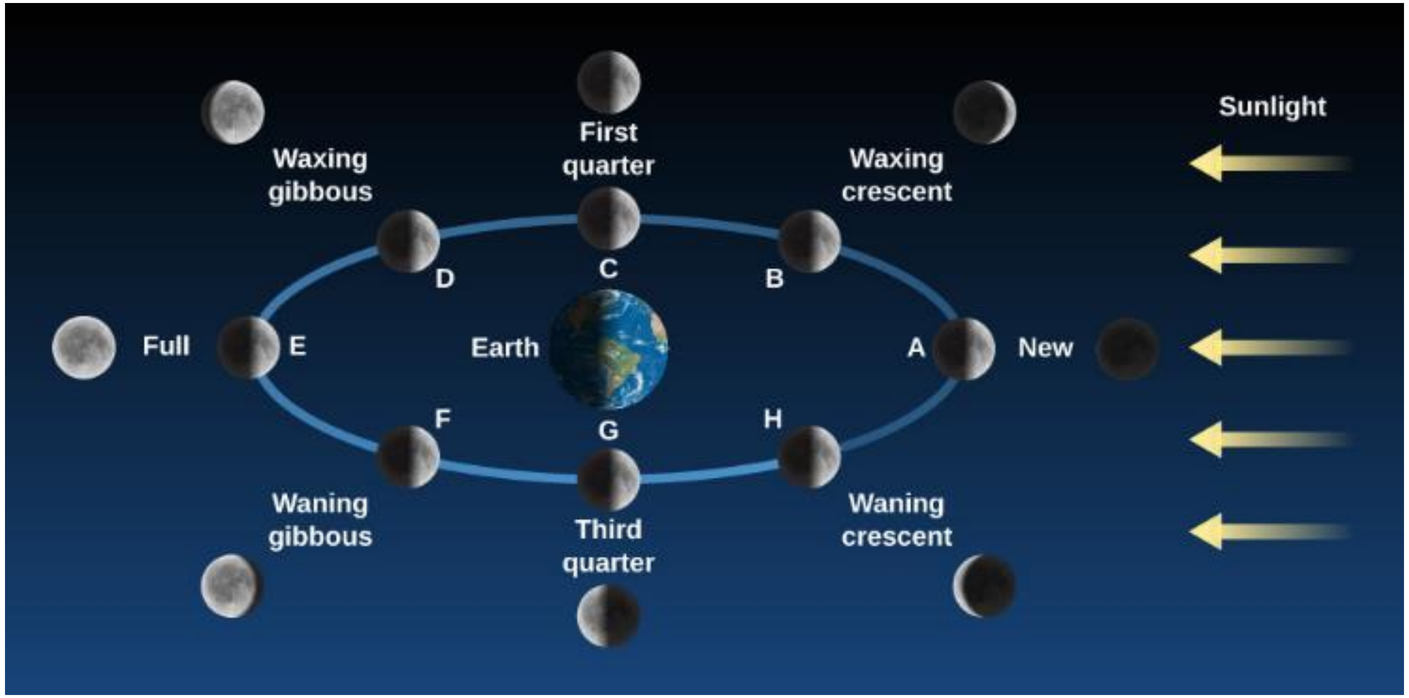
Phases of the Moon

Things to notice:

The night side of the Moon is always opposite the Sun (as is the Earth’s)

Using the blue circle to draw a line across the Moon, this represents the side of the Moon we can see from the Earth.

The image adjacent to the orbital picture shows how that phase appears in the sky.



Phases of the Moon

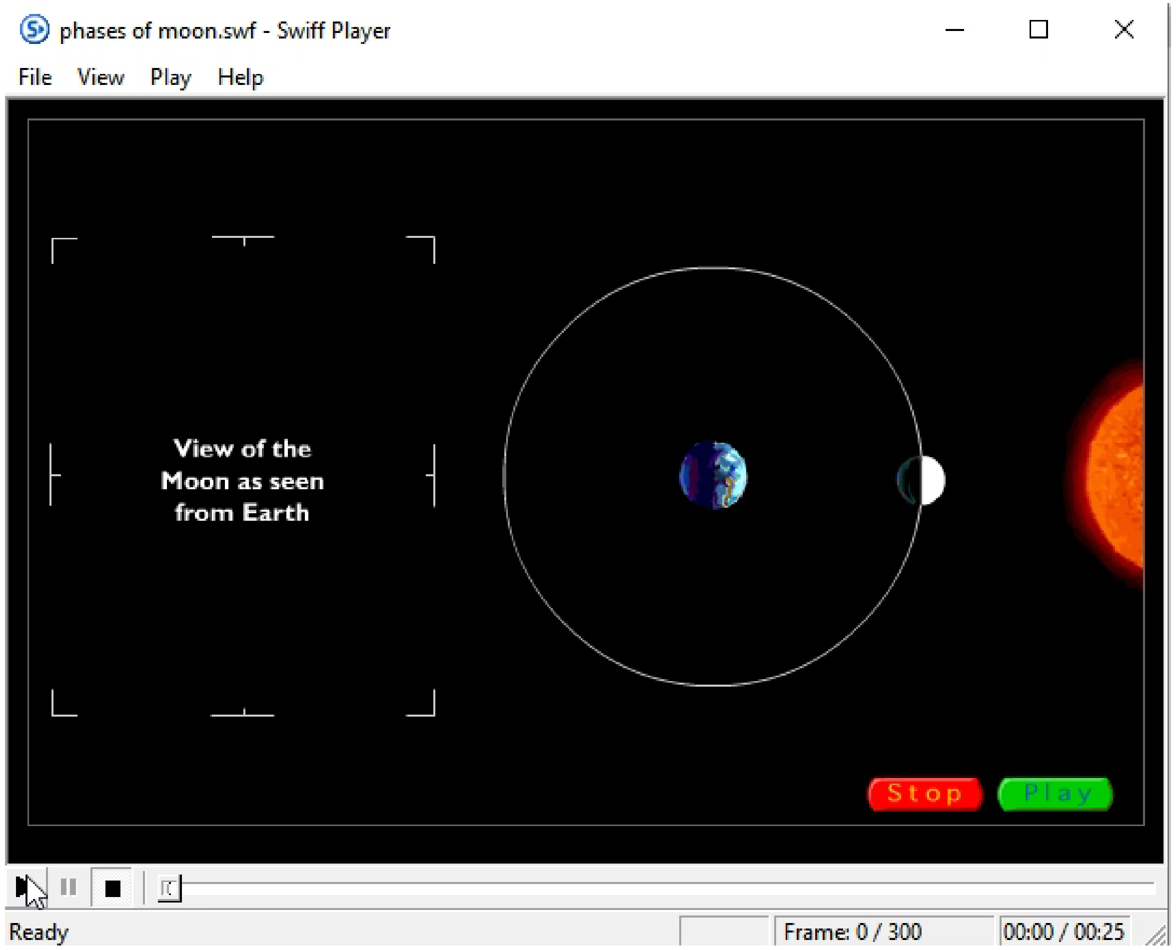
Phases of the Moon video :

As with the previous image, the night side of the Moon is always opposite the Sun (as is the Earth's)

The white part of the cone represents the portion of the Moon we can view from Earth that is not currently illuminated.

The yellow part of the cone shows the illuminated portion of the Moon viewable from the Earth.

The image to the left shows how the Moon appears in the sky.



Synchronous Rotation

(a)

(b)

The Moon without and with Rotation. In this figure, we stuck a white arrow into a fixed point on the Moon to keep track of its sides.

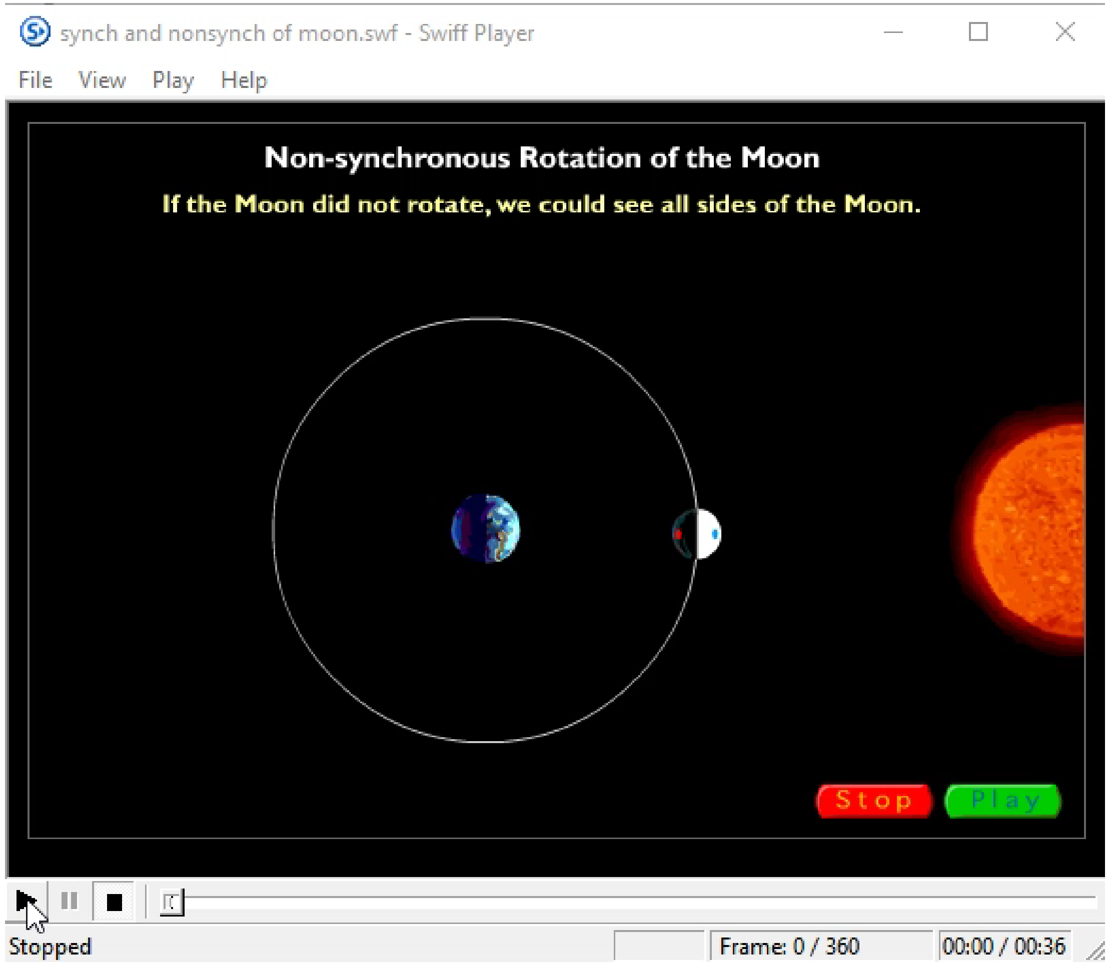
(a) If the Moon did not rotate as it orbited Earth, it would present all of its sides to our view; hence the white arrow would point directly toward Earth only in the bottom position on the diagram.

(b) Actually, the Moon rotates in the same period that it revolves, so we always see the same side (the white arrow keeps pointing to Earth).

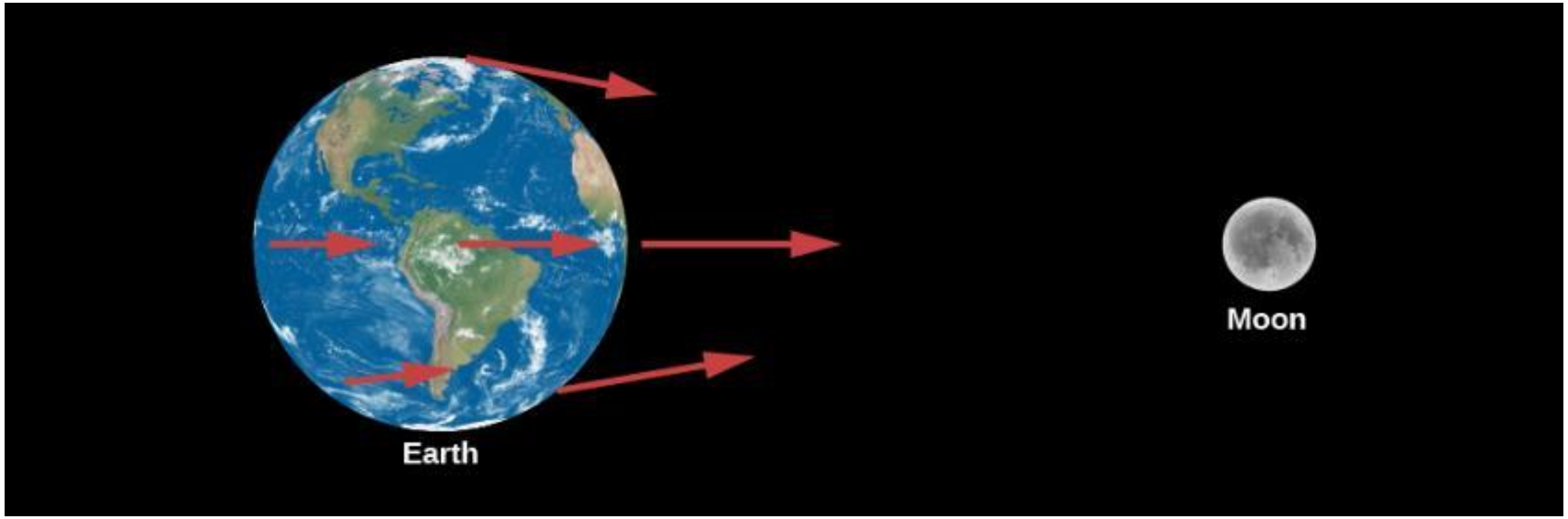
Synchronous Rotation

Synchronous Rotation Video:

- This video tracks 2 craters on the Moon (marked with red and blue dots).
- On the first orbit, it shows the Moon not rotating and that at some points one, the other, or both of the craters are visible
- On the second orbit, it shows as the Moon rotates at the same rate as it orbits, that only the blue crater is ever visible.



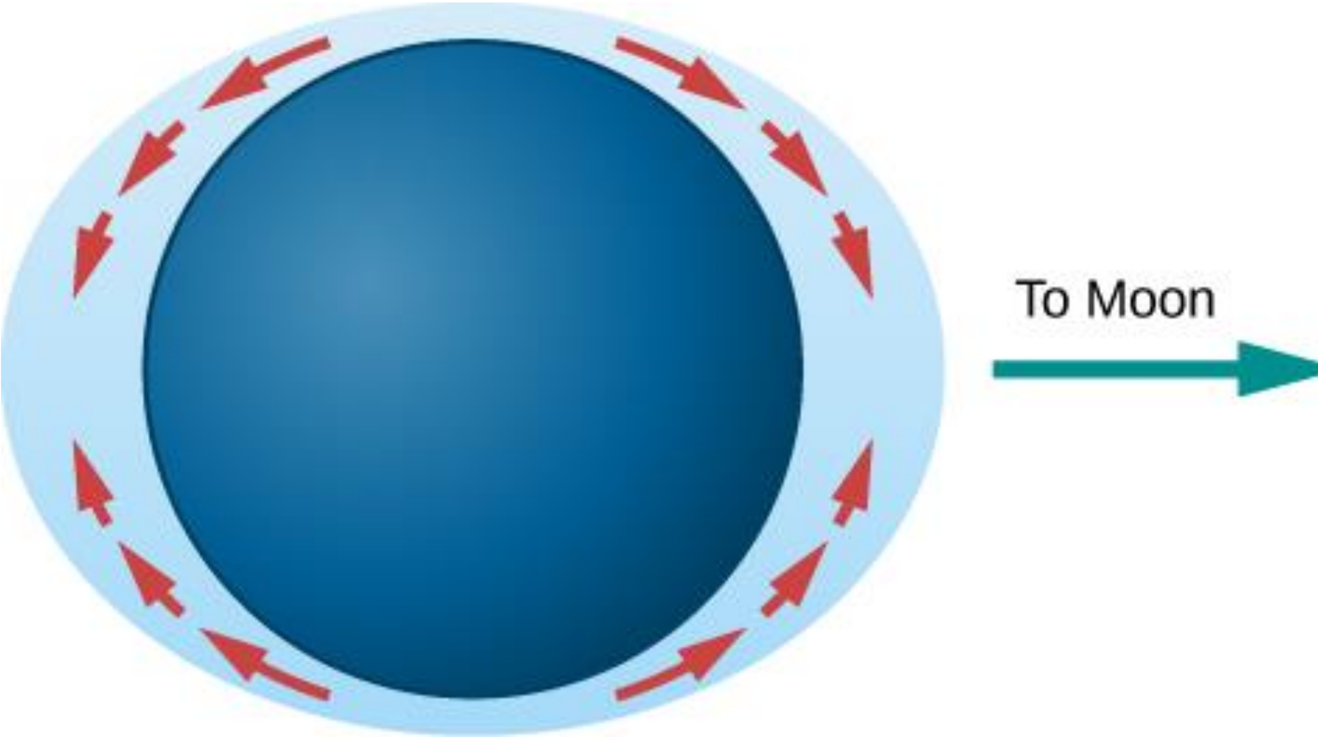
Tides



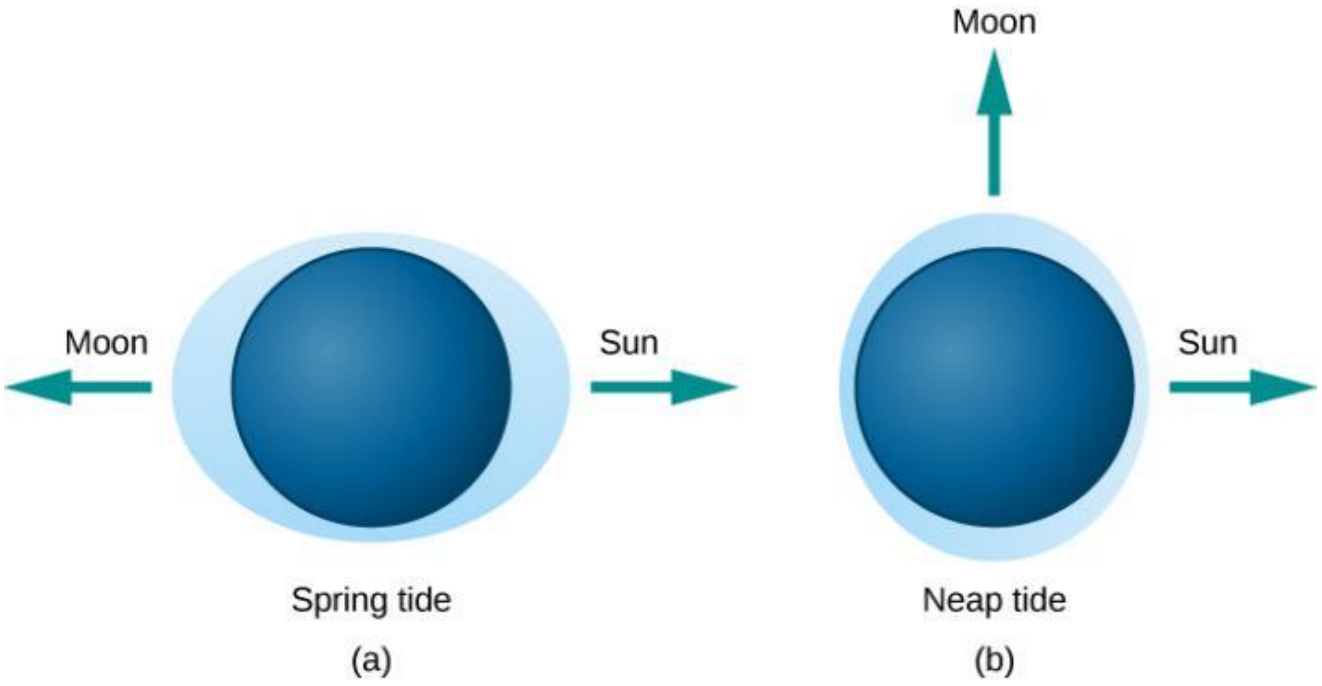
Pull of the Moon. The Moon’s differential attraction is shown on different parts of Earth. (Note that the differences have been exaggerated for educational purposes.)

Tides

Tidal Bulges in an “Ideal” Ocean. Differences in gravity cause tidal forces that push water in the direction of tidal bulges on Earth.



Tides



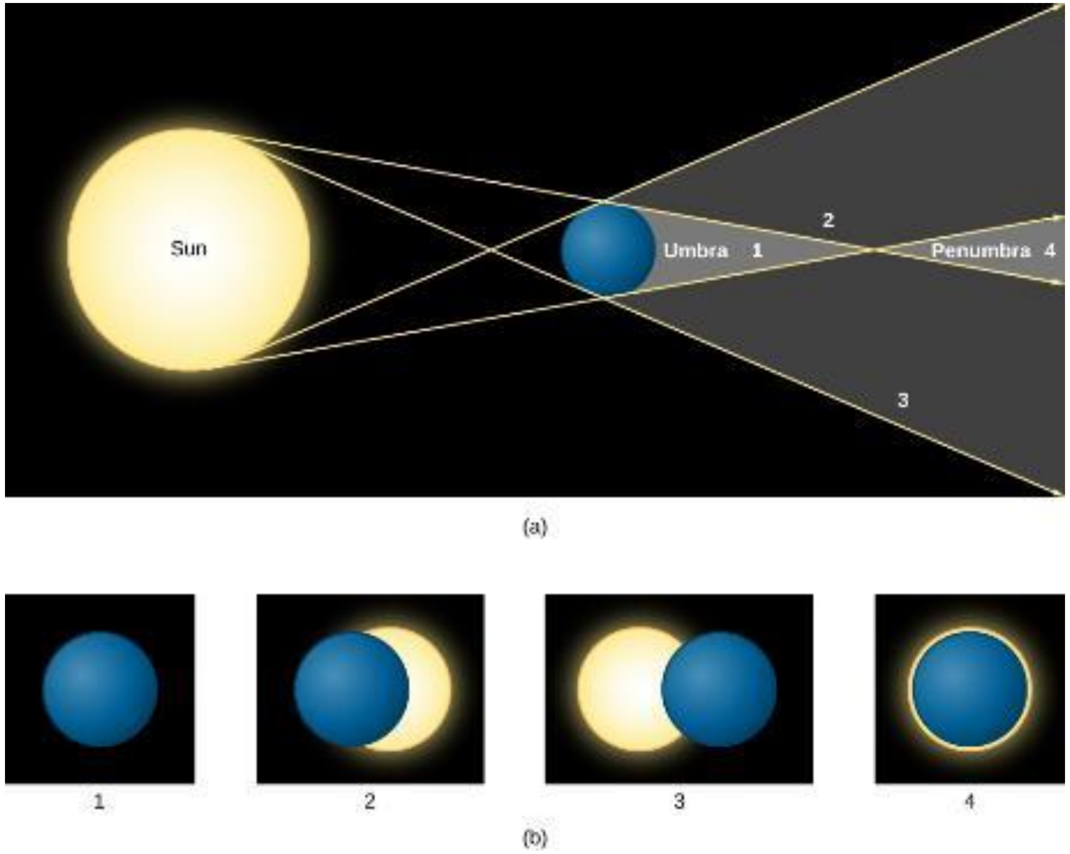
Tides Caused by Different Alignments of the Sun and Moon.

(a) In spring tides, the Sun’s and Moon’s pulls reinforce each other.

(b) In neap tides, the Sun and the Moon pull at right angles to each other and the resulting tides are lower than usual.

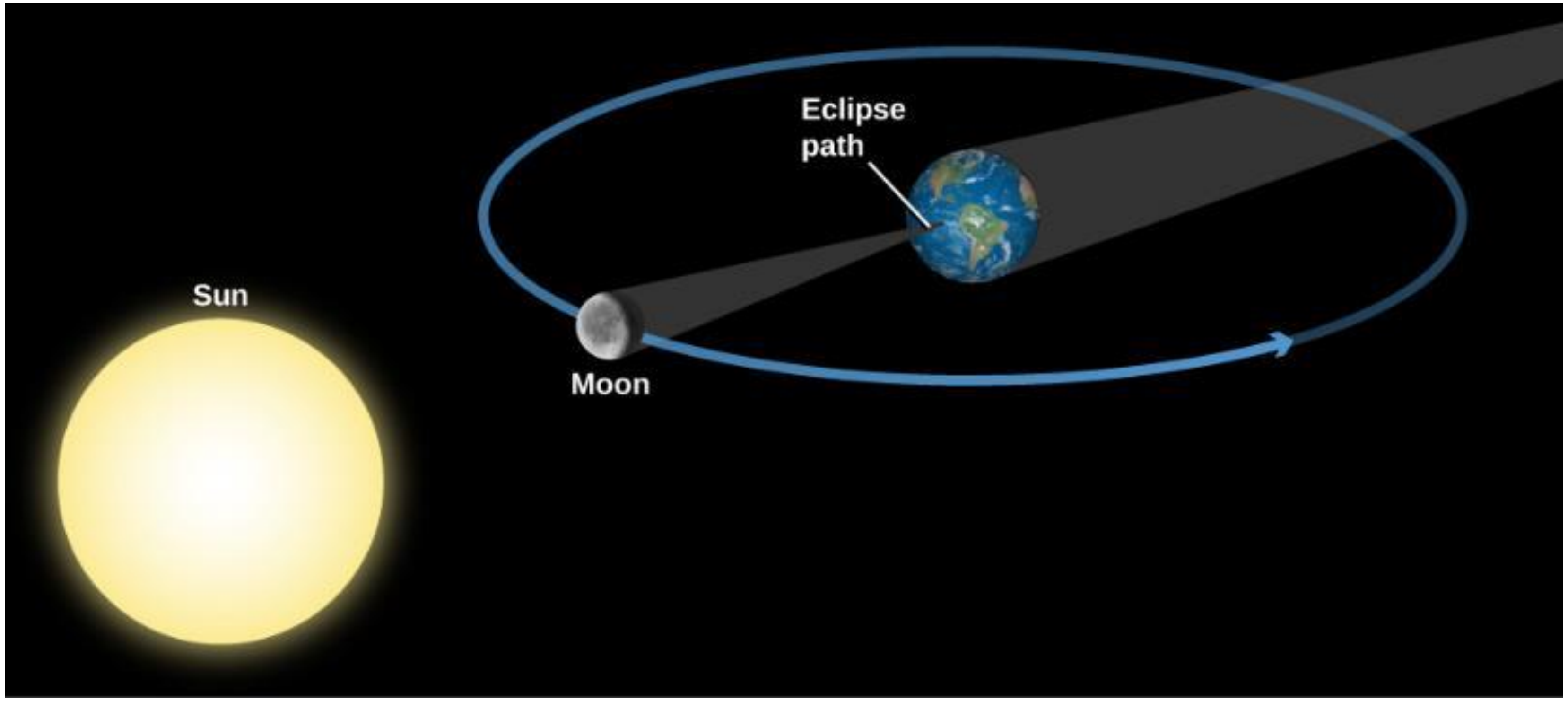
Lecture Section 4: Eclipses

Eclipses and Shadows



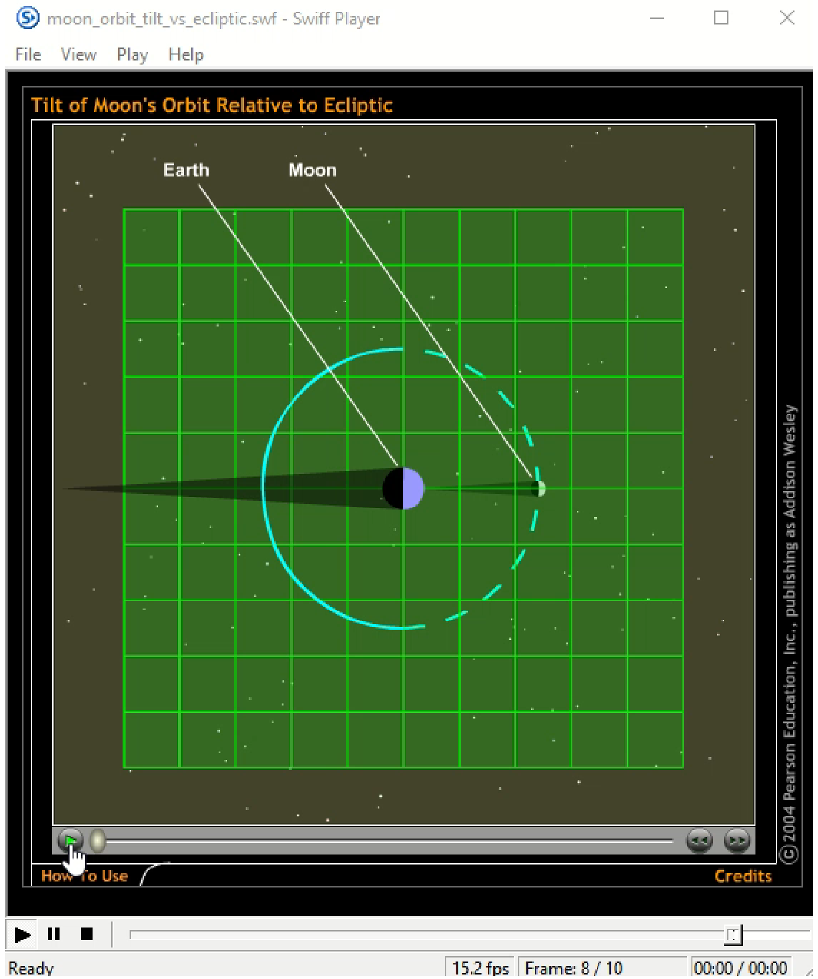
Solar Eclipse. (a) The shadow cast by a spherical body (the Moon, for example) is shown. Notice the dark umbra and the lighter penumbra. Four points in the shadow are labeled with numbers. In (b) you see what the Sun and Moon would look like in the sky at the four labeled points. At position 1, you see a total eclipse. At positions 2 and 3, the eclipse is partial. At position 4, the Moon is farther away and thus cannot cover the Sun completely; a ring of light thus shows around the Sun, creating what is called an "annular" eclipse.

The Moon’s Shadow



Geometry of a Total Solar Eclipse. Note that our diagram is not to scale. The Moon blocks the Sun during new moon phase as seen from some parts of Earth and casts a shadow on our planet.

The Moon's orientation



Eclipse video demonstration.

This shows a rotating view of the Earth and Moon's positions.

The Moon's orbit is inclined relative to the Earth's orbit around the Sun.

The dashed curve at the beginning, for example, shows the Moon's orbit below the ecliptic.

Only a perfect alignment will result in an eclipse.

Total Solar Eclipse

2017 Total Solar Eclipse.

This shows an image of the Sun during the 2017 total solar eclipse. The corona is clearly visible as ‘wispy’ light around the dark shadow of the Moon.

Annular Solar Eclipse

Annular Solar Eclipse.

This type of eclipse occurs when the Moon is near apogee (furthest point in its elliptical orbit from the Earth). Due to the larger distance, the Moon appears smaller and cannot fully cover the Sun, which results in a ring or annulus of light.

Partial Solar Eclipse

Partial Solar Eclipse.

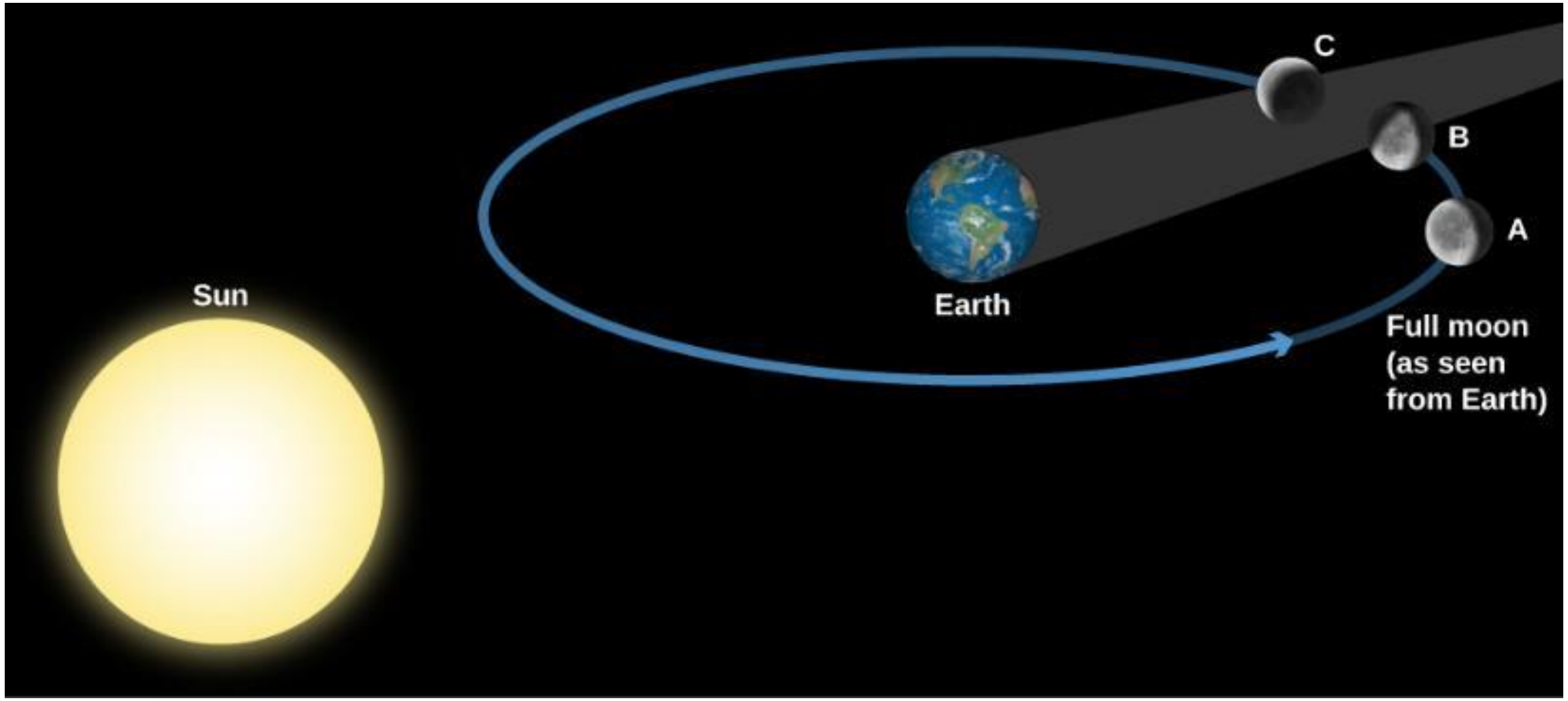
This occurs when a person's location on Earth is not in the direct shadow of the Moon.

The Moon’s Shadow

The Moon’s Shadow as viewed from Space.

This demonstrates that not everyone on Earth can observe a solar eclipse as the shadow on the Earth is much smaller than the size of the Earth.

The Earth’s Shadow



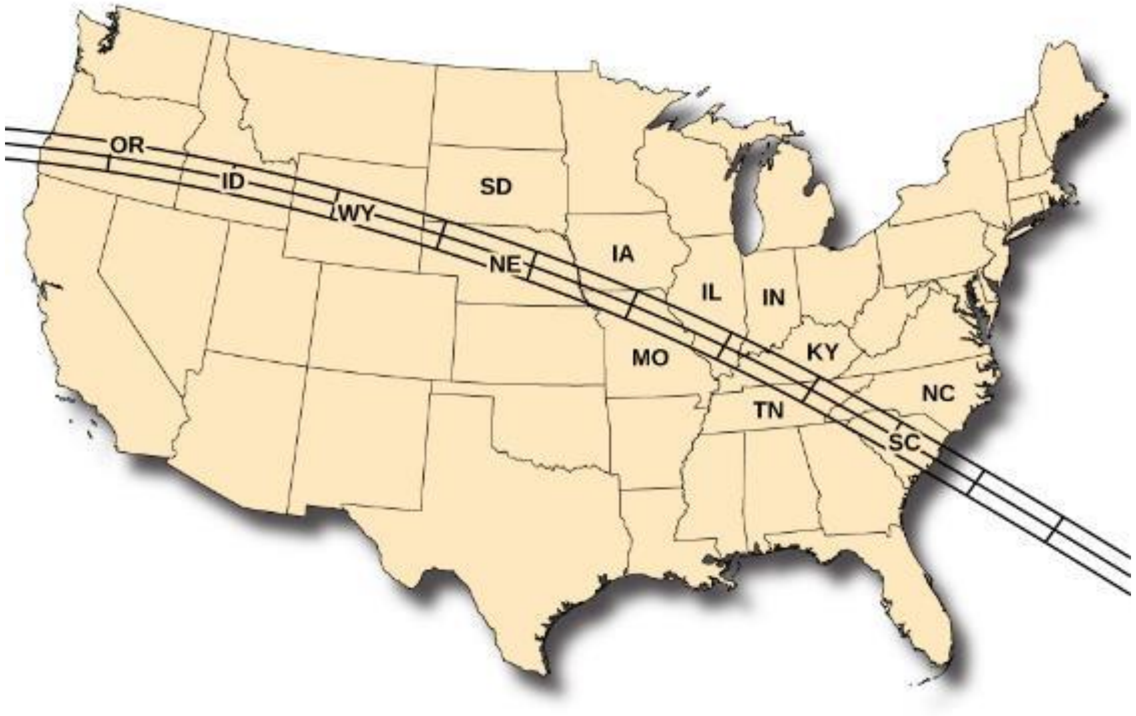
Geometry of a Lunar Eclipse. The Moon is shown moving through the different parts of Earth’s shadow during a total lunar eclipse. Note that the distance the Moon moves in its orbit during the eclipse has been exaggerated here for clarity.

Lunar Eclipse

Lunar Eclipse.

This shows the Moon as it goes through an umbral eclipse (i.e., it passes through the darkest part of the Earth's shadow). The alternative is a penumbral eclipse.

Eclipse Path



2017 Total Solar Eclipse. This map of the United States shows the path of the total solar eclipse of 2017. On August 21, 2017, the shadow will first cross onto the West Coast near Portland, Oregon, traversing the United States and exiting the East Coast in South Carolina approximately 90 minutes later, covering about 3000 miles in the process. (credit: modification of work by NASA)

Review Questions

Short: How long are solar and sidereal days?

Short: How do we describe positions of celestial objects on the celestial sphere?

Short: Be able to tell when the Full, New, and quarter moons rise/set.

Short: Why do we have a ‘far side’ of the Moon? (Also, is the far side the dark side?)

Short: How many people can see a solar eclipse? A lunar eclipse?

Short: Why do we not see an eclipse each month?

Long: Describe the mechanism that causes the seasons and explain how it provides warmer summers and colder winters.

Long: Be able to label every part of the Moon’s orbit and show what it looks like at each position.

Long: What are the different kinds of eclipses and why are each one different (all 5 different kinds)?

Credit

Credit: Openstax