

 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.



• **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.



• **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.



 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.



http://burro.cwru.edu/Academics/Astr306/Coords/coords.html



• 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.



• 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)

Figure 4.15







- 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).



• **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.)



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

Tidal Forces



Forces relative to the Sun (or primary body)



Forces relative to the center of the Earth

Differential (tidal) forces on a body relative to the primary (left), and relative to its own center (right). The forces relative to its center stretch the body along the line joining the body and the primary, and compress the body along the perpendicular directions, to form a football shape (prolate spheroid).

Courtesy Prof. Dale Gary



• **High and Low Tides.** This is a side-by-side comparison of the Bay of Fundy in Canada at high and low tides. (credit a, b: modification of work by Dylan Kereluk)



- 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.

Tidal Locking

- The tidal forces of the Earth act on the moon to distort its shape.
- Note what happens when a rotating body is tidally distorted. The line of distortion is continually being rotated away from the line between the two bodies, causing the bulges to lead slightly. There is then a net torque opposing the direction of rotation, thus slowing down both bodies.
- This torque exists until the slowing rotation causes the body's orbital period to equal its rotational period. Once this happens, the body is said to be *tidally locked*, and the torque and dissipation by *tidal forces ceases*.

- That is why the Moon keeps the same face to the Earth.



• 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.

• 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.

• **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 crossed onto the West Coast near Portland, Oregon, traversed the United States and exited the East Coast in South Carolina approximately 90 minutes later, covering about 3000 miles in the process. (credit: modification of work by NASA)

Figure 4.23

• **The Sun's Corona.** The corona (thin outer atmosphere) of the Sun is visible during a total solar eclipse. (It looks more extensive in photographs than it would to the unaided eye.) (credit: modification of work by Lutfar Rahman Nirjhar)

Time Lapse Total Solar Eclipse

http://www.nikonusa.com/en/Learn-And-Explore/Article/h20zakgu/how-to-photograph-a-solar-eclipse.html#!/media:image:SolarEclipse-Espenak-T01-03_01.jpg

Time Lapse Annular Eclipse

UC Davis physicist <u>Marusa Bradac took this timelapse of the May 20 solar eclipse from Tahoe City</u> http://blogs.ucdavis.edu/egghead/2012/05/21/eclipse-photos-any-more/

NASA Mars Rover Views Eclipse of the Sun by Phobos

http://www.jpl.nasa.gov/news/news.php?release=2013-263

• **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.

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http://www.astro.virginia.edu/~rjp0i/takingmeasure/parallax.shtml

360-deg = 15 deg/hr 24 hrs

Celestial Equator

The Celestial Equator is up (90°- your Latitude) from the S horizon

Right Ascension

SUMMARY

• Tilt of the earth's axis

- Seasons
- Tropics

Eclipses of the sun and moon

- Total
- Partial
- Annular

Tides and tidal locking

- How many tides per day?
- Rotation of the moon

Coordinate Systems

- Latitude and longitude
- Declination and right ascension