**The Solar System**

Textbook: Chapter 15 \*This is RECOMMENDED READING

What are some possible challenges early astronomers had to deal with, in their attempts to discover how celestial bodies were arranged?

**Part A: 15.1 Ancient Astronomy**

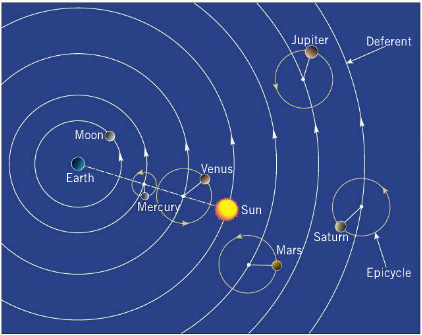
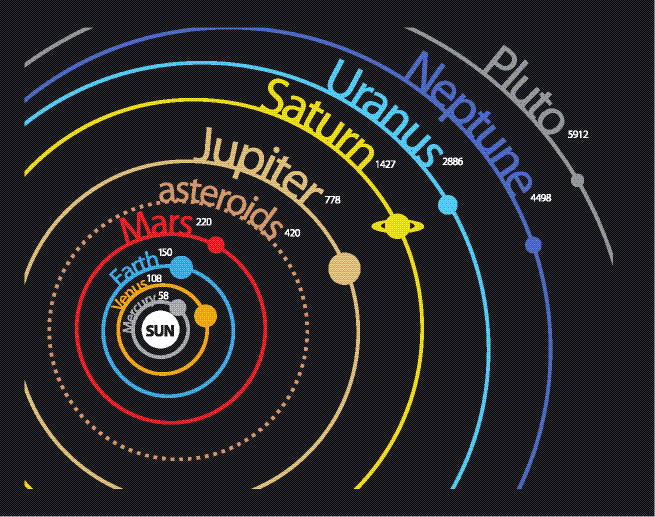
**Important Terminology**

**a) Orbit:** One object moving a fixed distance around another.

**b) Rotation:** Object spinning on its axis (creates night and day on Earth).

**c) Revolution:** Object completing one orbit (365 days on Earth = 1 year).

**d) Astronomical unit (AU):** unit of length that is roughly the distance from the **EARTH** to the **Sun** which is 150, 000, 000 kilometers.

 ****

What is the major difference between these two pictures?

See Explanation.
Moving the cursor over the image will bring up an annotated version.
Clicking on the image will bring up the highest resolution version
available.- Ptolemy, an ancient astronomer, believed in a **geocentric (earth centered) universe** which differs from the current **heliocentric (sun centered) universe**

The first main piece of evidence that questioned the geocentric model was **retrograde motion**

* The apparent backward motion of a planet viewed from earth

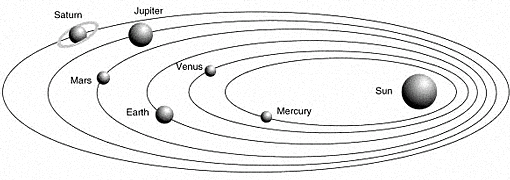
|  |  |
| --- | --- |
| **Ptolemy**  **(Geocentric Model)** | **Copernicus**  **(Heliocentric Model)** |
| **http://www.yorku.ca/slater/images/3-retrogrademotionptolemy_000.jpg** | Image result for retrograde motion |
| Planets have epicycles which cause the apparent backward motion | Inner planets move faster than outer planets |

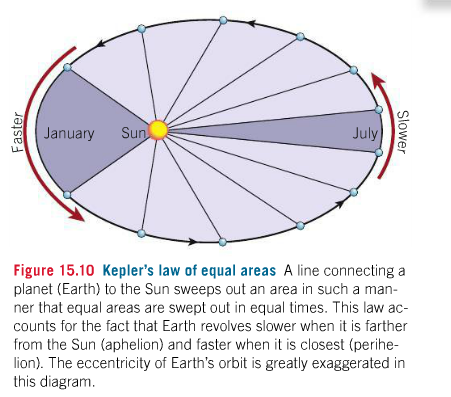
**Animated photo of retrograde motion** [**http://apod.nasa.gov/apod/ap011220.html**](http://apod.nasa.gov/apod/ap011220.html)

**Part B: 15.2 Modern Astronomy**

The following astronomers found evidence that lead to our current understanding of the Solar System

|  |  |  |
| --- | --- | --- |
| **Copernicus** | Image result for heliocentric model circular orbits | Heliocentric model with **circular orbits** |
| **Kepler** |  | Three planetary laws of motion |
| **Newton** |  | First to formulate and test the law of **universal gravitation**. |

****Let’s add some more detail to Kepler’s three laws of planetary motion

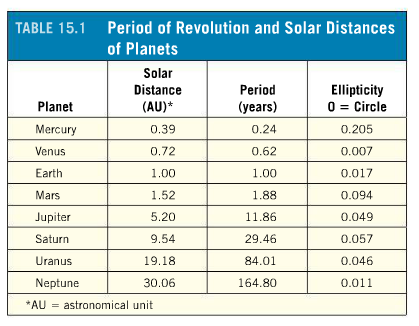
1. The path of each planet around the sun is **elliptical**
2. An orbiting planet will always cover the same amount of **area** in a given time

What happens to Earth’s orbital speed in January?

**INCREASES**

What phenomenon allows this to occur?

**Gravity; smaller distance between Earth and Sun in January means that Earth can move faster**

1. The orbital periods for the planets and their distances to the sun are proportional. Solar Distances of planets can be measured if their periods of revolution are known. Useful because we can’t go into space to measure them ourselves

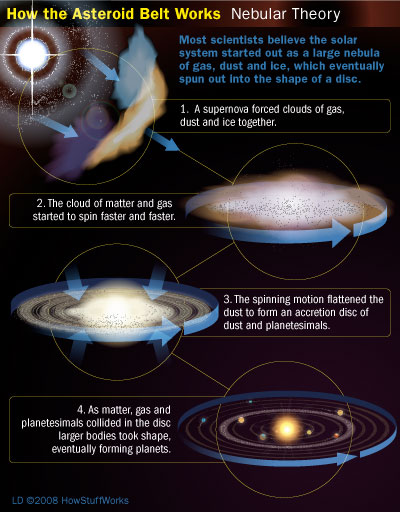
For example:

**Mars has an orbital period of 1.88 years, 1.88 squared equals 3.54, cube root of 3.54 is 1.53**

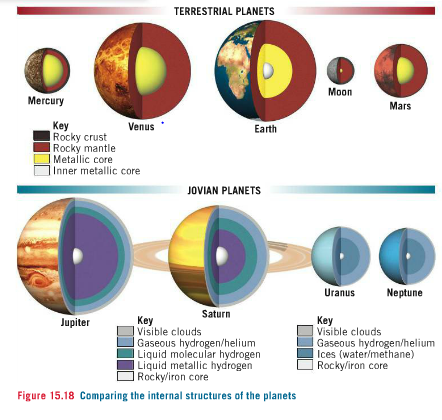
**Part C: 15.3 Our Solar System**

Why do we need to learn about the formation of our solar system?

**Nebular Theory:** explains the formation of the solar system. The sun and planets formed from a rotation cloud of interstellar gases and dust called **solar nebula**.

1. The solar nebula contracted due to gravity and formed the hot **protosun**
2. The remaining material formed a thick, flattened, rotating disk that started to cool and condense into icy, rocky material
3. The material collided multiple times causing them to clump together to create larger asteroid sized chunks called **planetesimals.**
4. The asteroid sized rocky bodies collided and combined to form **protoplanets**

Why might the inner planets have a different composition than the outer planets (rocky, metals vs. gas, ice, ammonia)



**Terrestrial Planets (Inner planets):** Earth like planets (**Mercury, Venus, Earth, Mars)**

**ASTEROID BELT**

**Jovian Planets (Outer planets):** Jupiter like planets (**Jupiter, Saturn, Uranus and Neptune)**

* + Ice composition accounts for their larger sizes

**Pneumonic to Remember the Planets Order**

My Very Easy Method Just Set Up Nine Planets

E E A A U A R E L

R N R R P T A P U

C U T S I U N T T

U S H T R U U O

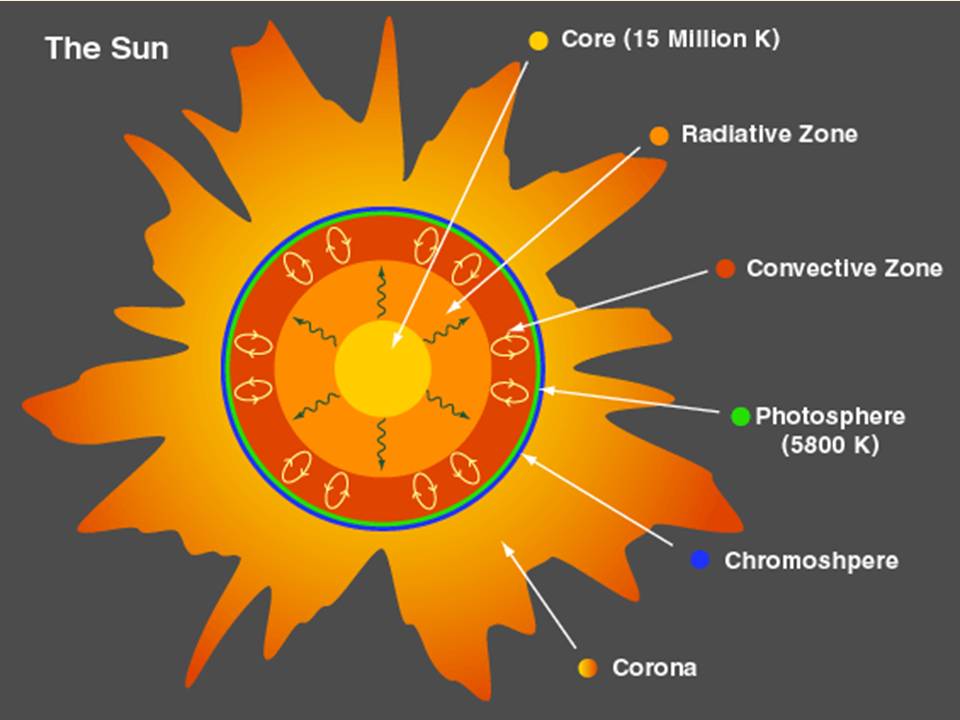
R E N S N

Y R E

**Part D: The Sun**

**The Suns layers**

The sun and its atmosphere have 6 main layers or zones:



|  |  |  |
| --- | --- | --- |
| **Sun Layer** | **Characteristic** | **Temperature (°C)** |
| **Core** | Fusion of H into He | 15,600,000 |
| **Radiative Zone** | Cooler and less dense than the Core; Energy travels by radiation and takes 100,000 years to travel through. | 8,000,000 |
| **Convective Zone** | Convection currents carry energy to the Sun’s surface. | 1,500,000 |
| **Photosphere** | Visible surface of Sun. Energy transported by radiation and light is produced here. | 6,000 |
| **Chromosphere** | Inner atmosphere, energy transported by radiation, temperature causes H to emit reddish light | 20,000 |
| **Corona** | Outer atmosphere, produces solar wind. | 1,000,000 |

**The Sun’s Features**

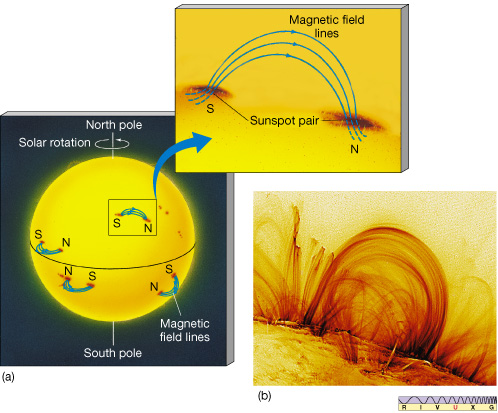
Take a look at this infographic to see some of the Sun’s features: <http://www.space.com/12047-solar-flares-sun-storms-space-weather-infographic.html>

**a) Sunspots**

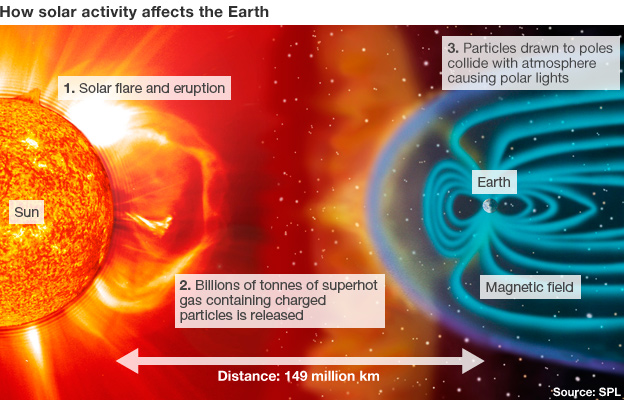
* Sunspots are dark spots on the Sun’s **photosphere** and are very hot and bright.

Why do sunspots appear dark coloured from Earth?

**Photosphere is much hotter and brighter, so they appear relatively dark.**

\*View [Hale Explains Sunspots](http://www.bbc.co.uk/science/space/solarsystem/sun_and_planets/sun#p005xg9q)

* caused by variations in the Sun’s magnetic field that are 1000x stronger than what is found in the surrounding photosphere.
  + These strong magnetic fields trap and cool rising hot gas
  + responsible for massive releases of energy called solar flares.

**b) Solar Wind and Magnetic Storms**

\*View [Raging Solar Wind](http://www.bbc.co.uk/science/space/solarsystem/sun_and_planets/sun#p005xg9b).

**Solar wind:** a stream of **protons** and **electrons** given off by the corona in two ways:

i) **Coronal Holes**: Large openings in the corona, allow solar wind to pour out.

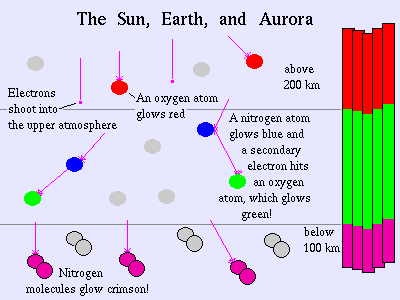
ii) **Solar Flares**: Outbursts of light that come out of sunspots. Follow an 11 year cycle.



How is the Aurora Borealis (Northern Lights) produced?

**Interactions between Earth’s magnetic field and solar wind particles. They follow lines of magnetic force created by Earth’s core.**

* Magnetic and electrical forces interact with each other in shifting patterns, making it look like auroras are dancing across the sky.

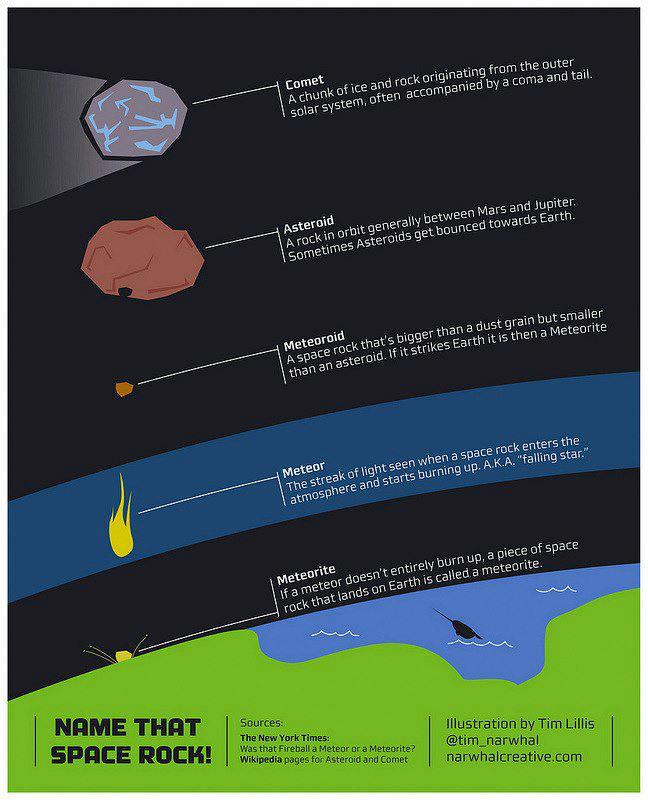


What determines the colour of the Aurora?

**Which atom the charged particles encounter in Earth’s atmosphere.**

Watch this video to see the Aurora Borealis in action: <https://www.youtube.com/watch?v=fVsONlc3OUY>

**Part E: Solar System Debris**

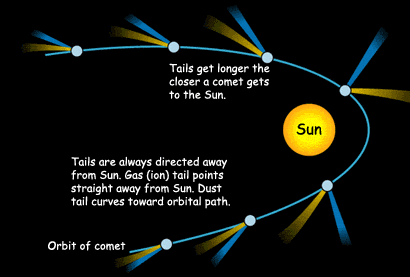
**

1. **Comets**

****

What are comets made of?

**dust particles, frozen H2O, CO2, Methane, Ammonia.**

* Typically found in the Kuiper Belt beyond Neptune’s orbit, but some travel in elliptical orbits closer to the sun.

\*View [The Late Heavy Bombardment](http://www.bbc.co.uk/science/space/solarsystem/other_solar_system_bodies/comet#p006x4v3).

Why are comets important to life on Earth?

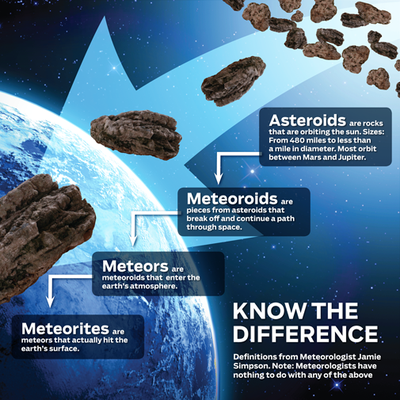
**-As much as 50% of Earth’s water came from comets.**

**2) Asteroids**

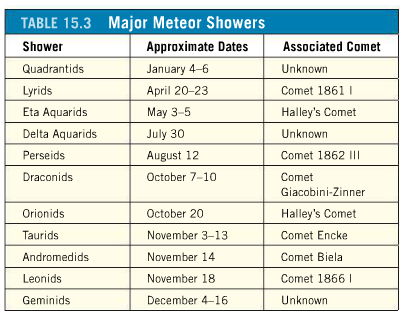
-Asteroids are **planetesimals** remaining from the formation of the Solar System and most orbit the sun between Mars and Jupiter.

\*View [Tracking Killer Asteroids](http://www.bbc.co.uk/science/space/solarsystem/other_solar_system_bodies/asteroid#p00bm4vj).

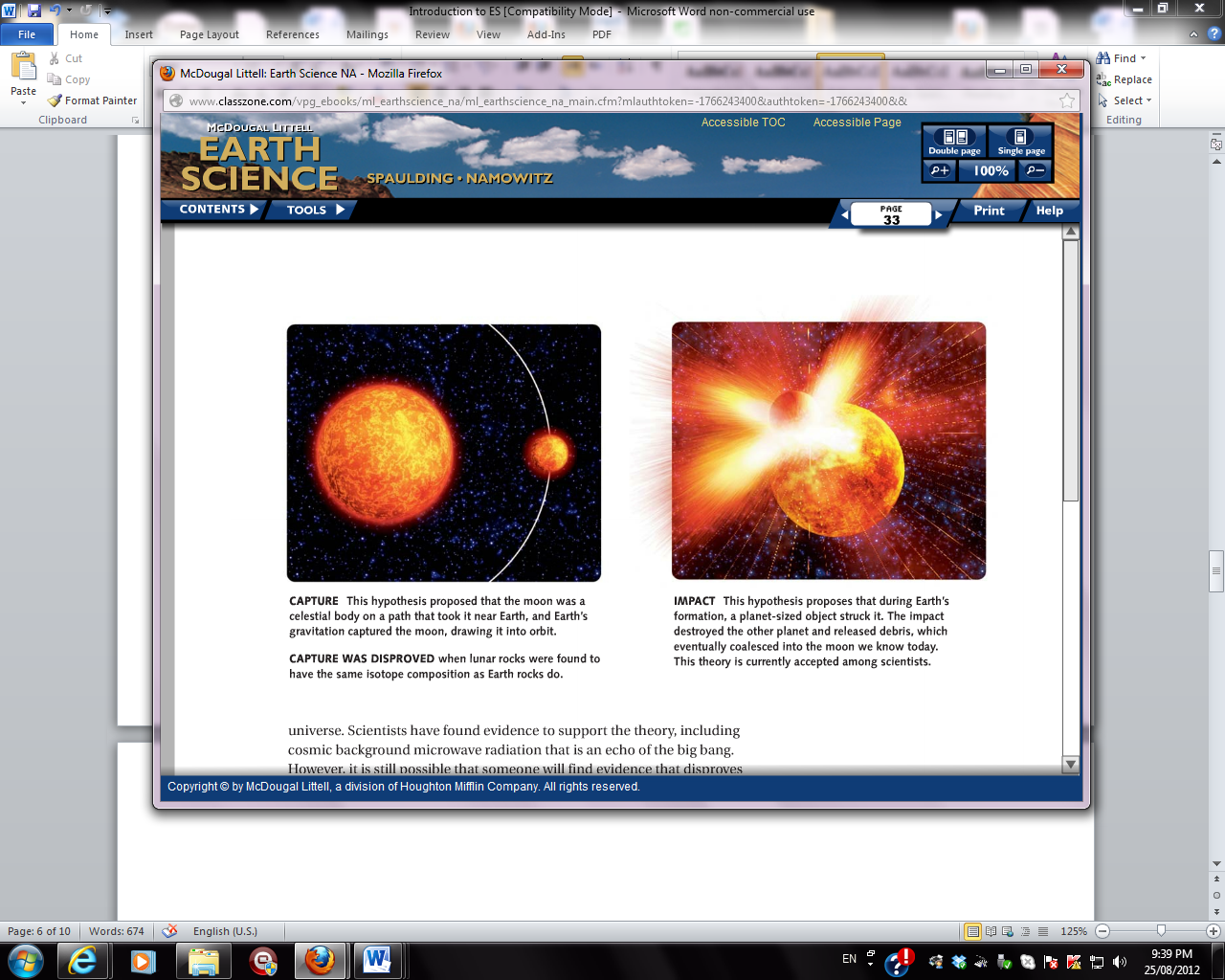
**3) Meteoroid, Meteor and Meteorite**



|  |  |
| --- | --- |
| **Meteoroids** | Pieces of asteroids that range from a grain of sand to 100 m in diameter |
| **Meteors** | **“falling star”**  The light produced when a meteoroid enters Earth’s Atmosphere |
| **Meteorites** | Meteorites that hit Earth’s Surface |

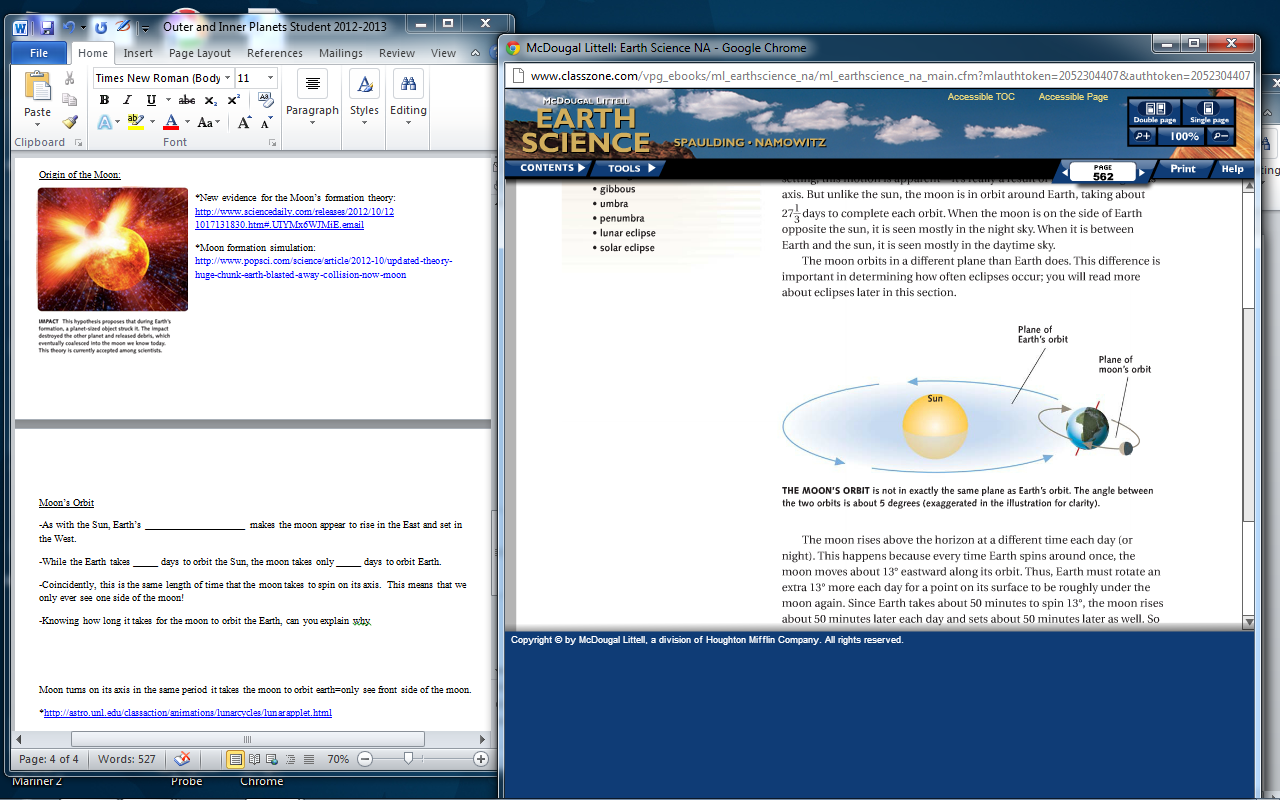
* Most meteorites are burnt up in Earth’s atmosphere and do not leave impact
* There are actually only 150 known impact craters on Earth!
* A meteorite crashed into [Russia](http://www.youtube.com/watch?v=1kvHl5Qcnzc) in 2013.
* Asteroids are rich in [resources](http://www.youtube.com/watch?v=7fYYPN0BdBw) that can be rare on Earth.

**Part F: Earth’s Moon**

* Formed by a collision between a Mars-sized body and Earth.
  + The ejected material was thrown into orbit around Earth and aggregated to form the Moon.

\*View a [simulation](http://www.popsci.com/science/article/2012-10/updated-theory-huge-chunk-earth-blasted-away-collision-now-moon) of the collision.

* ¼ the diameter of Earth, 1/6th the gravity of earth

**1) Moon’s Orbit**

* The moon’s orbit is **elliptical**
* It is not on the same plane as Earth’s orbit
  + It is different by 5 degrees
* Moons orbit takes **29.5 days**

**2) Moon’s Phases**

The moon’s phases are its daily changes in appearance because:

a) We only see the moon because it reflects **sunlight.**

b) Moon is in orbit around Earth.

Phases are either:

|  |  |
| --- | --- |
| **Waxing** | **Waning** |
| 2 weeks when moon changes from all dark to all light  (New to Full Moon) | 2 weeks, all light to all dark  (Full to New Moon) |

*\*Complete Phases of the Moon Oreo Lab*

-There are five different types of moon phases. Test your understanding by matching phase names to the correct description and providing an illustration in the space provided:

|  |  |  |
| --- | --- | --- |
| Phases | Definition Letter | Illustration |
| 1. New Moon |  |  |
| 2. Crescent Moon |  |  |
| 3. Quarter Moon |  |  |
| 4. Gibbous Moon |  |  |
| 5. Full Moon |  |  |

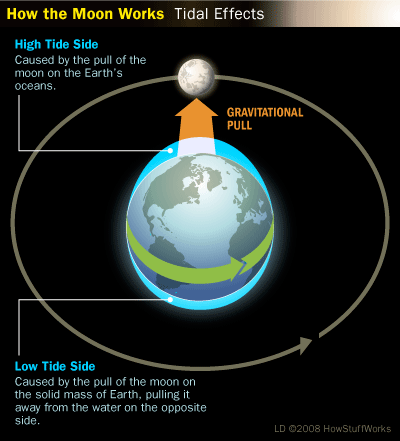
a. Brightly lit face is away from Earth, resulting in no visible moon.

b. Half of the moon faces Earth. Half of this is bright and the other half is dark.

c. Brightly lit face is completely visible from Earth.

d. A small sliver of the brightly lit face can be seen from Earth.

e. Almost all of the brightly lit face can be seen from Earth

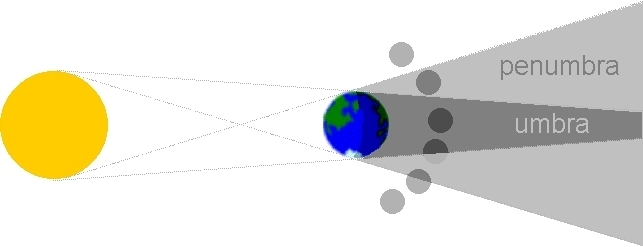
* Ocean water is kept at equal levels because of the balance between **gravity and centrifugal force**

What causes tides?

**Gravitational forces between the sun and the moon**

* The moons gravitational forces are strong enough to disrupt this balance by **accelerating** the water towards the moon
* this causes the water to bulge. As the earth and moon rotate the bulge also moves.
  + where bulges occur are high tide and therefore other areas are low tide

**3) Eclipses**

*****a) Lunar Eclipses*

* Lunar eclipses involve the moon falling into Earth’s **Penumbra** (partial shadow) or **Umbra** (complete shadow).

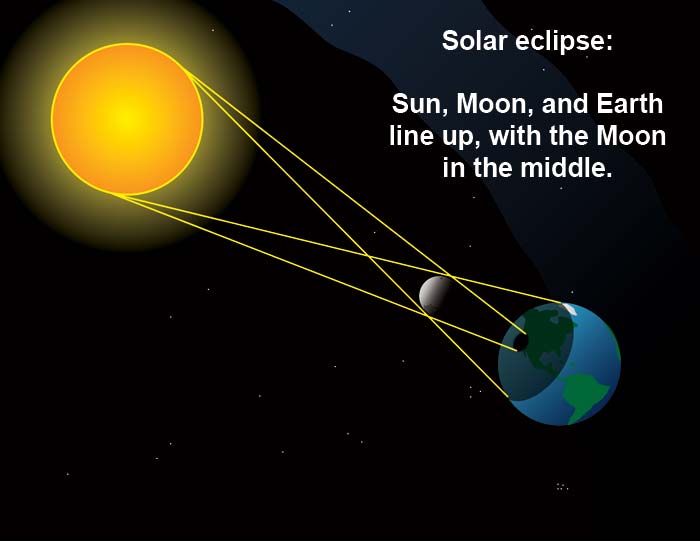
Why can lunar eclipses only occur during a full moon?

**Only time the moon is in Earth’s shadow.**

Why isn’t every full moon produce a lunar eclipse?

**Not every full moon falls into the umbra**

\*View the [Lunar Eclipse animation](http://astro.unl.edu/classaction/animations/lunarcycles/shadowsim.html) to see the idea in action.

*b) Solar Eclipses*

Solar Eclipses happen every year but Vancouver will only see one every 400 years. Why?

**-Umbra’s cone is very narrow and only covers 270km of Earth’s surface. You need to be inside that cone to see a total eclipse.**

**Your Turn!**

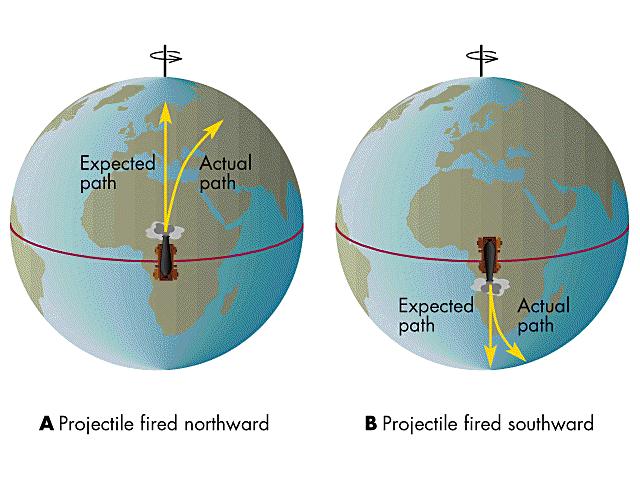
Draw a diagram of each type of eclipse below. In your own words, describe why they can only be seen at full and new moon phases, respectively

|  |  |
| --- | --- |
| **Lunar Eclipse** | **Solar Eclipse** |
|  |  |
|  |  |

-To see when the next solar eclipses will be visit:

<http://astro.unl.edu/classaction/animations/lunarcycles/eclipsetable.html>

<http://eclipse.gsfc.nasa.gov/SEmap/SEmapNA.html>

**Part H: Earth’s Motion and Structure**

**1) Earth’s Rotation**

* Earth’s rotation is its movement around its **axis.** One full rotation occurs every **24** hours.

There are two main pieces of evidence for Earth’s rotation:

**i) Foucault’s Pendulum:** Appears to change its path by 11° per hour as Earth **rotates** beneath it.

**ii) Coriolis Effect:** Path of air movement is deflected by Earth’s rotation.

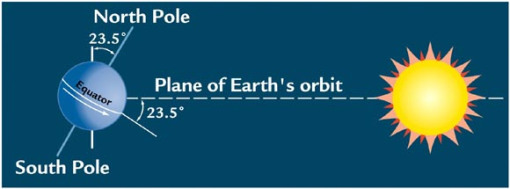
*\*View* [*Coriolis Effect*](http://www.youtube.com/watch?v=mcPs_OdQOYU) *between 2 and 11 minutes and* [*What is the Coriolis Effect?*](http://www.youtube.com/watch?v=Wda7azMvabE)

Why do Hurricanes spin?

*\*Watch this video on the Coriolis Effect:* [*https://www.youtube.com/watch?v=I48dGDf4Yh4*](https://www.youtube.com/watch?v=I48dGDf4Yh4)

***a) Axis and Rate of Rotation***

* Earth’s axis is an imaginary line between the North and South Poles.
* The imaginary path on which Earth revolves around the Sun is called its orbital plane.



Does Earth’s axis and orbital plane form a right angle?

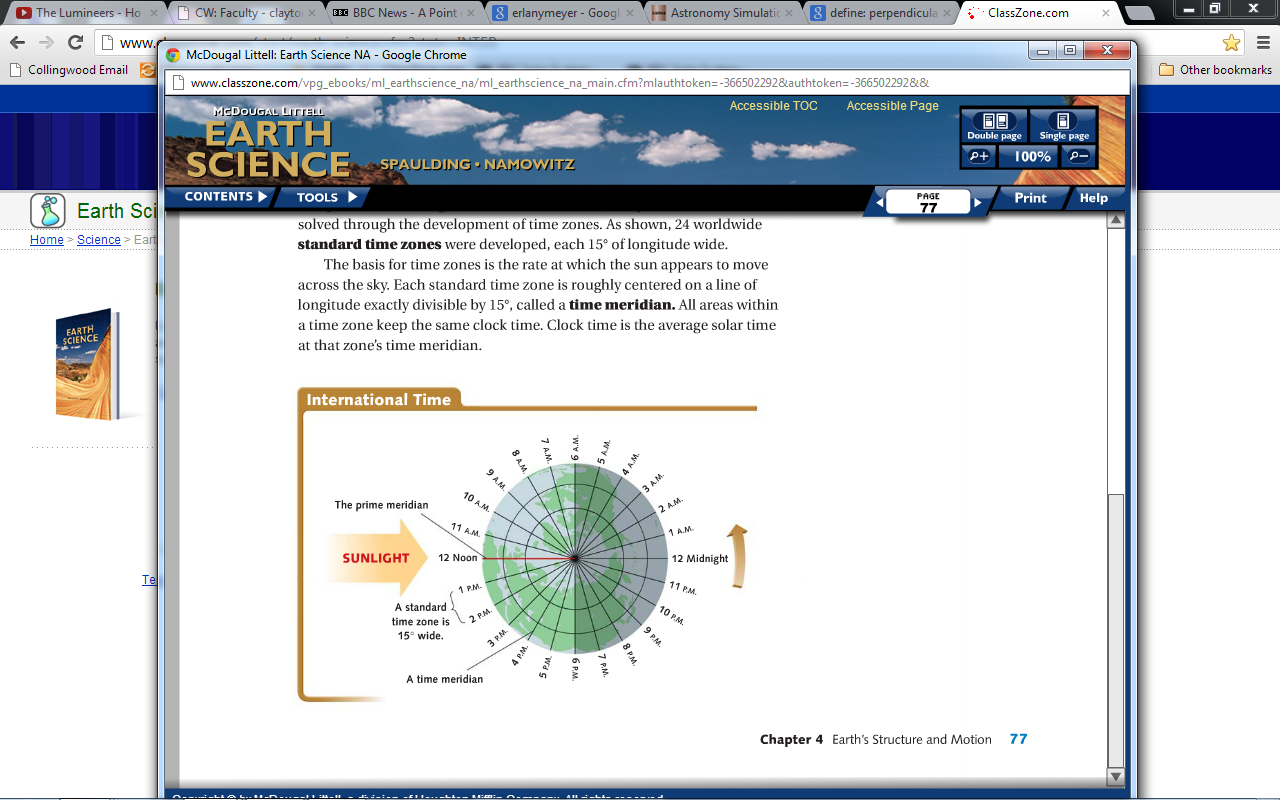
**No, Earth’s axis is at a 23.5° angle from the orbital plane. This is important!**

Do all locations on Earth rotate at the same speed?

**No, Earth is not a perfect sphere = speed varies by latitude.**

**-Poles: Axis of rotation = speed of rotation is almost 0.**

**Boston: 1300 km/hr Equator: 1690 km/hr**

***b) Effect of Earth’s Rotation***

What are some obvious effects of Earth’s rotation?

**-Day/night, coriolis effect, Foucault’s Pendulum…**

**Earth’s rotation also creates time:**

* Earth rotates **360** degrees every **24** hours, averaging **15** degrees/hour.
  + Standard time zones reflect this average as they are also **15** degrees wide.



* + The **Prime Meridian** is 0 degrees longitude and is the starting point for international time zones.
    - Moving west from Greenwich, England means that you must set your clock **back 1 hour every 15 degrees.**
  + The international date line is located **180** degrees from Greenwich.



* + - Moving west of the International Date Line means that you must set your clock **back 1 day!**
  + When moving overland, most time zones are not straight in order to account of local needs (see B.C.’s time zone).

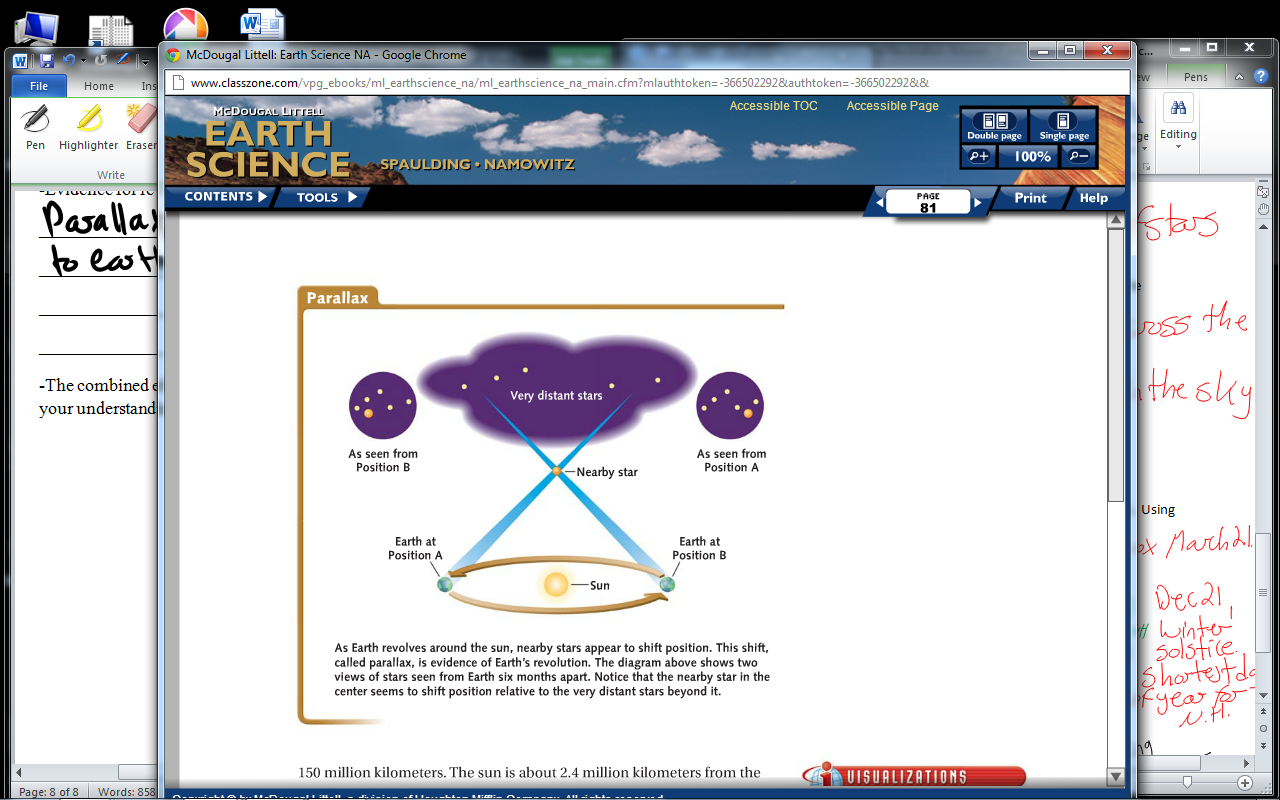
\*View BBC’s [History of Time Zones](http://www.bbc.co.uk/news/world-12849630).



\*See the future of time [too](http://www.bbc.co.uk/news/science-environment-12787502).



1. **Earth’s Revolution**

* **orbit around the sun.**

How are Earth’s rotation and revolution different in their effects on the apparent motion of the sun?

**Rotation: Creates days and nights by moving the sun across the sky daily.**

**Revolution: Makes the sun’s path across our sky change throughout the year.**

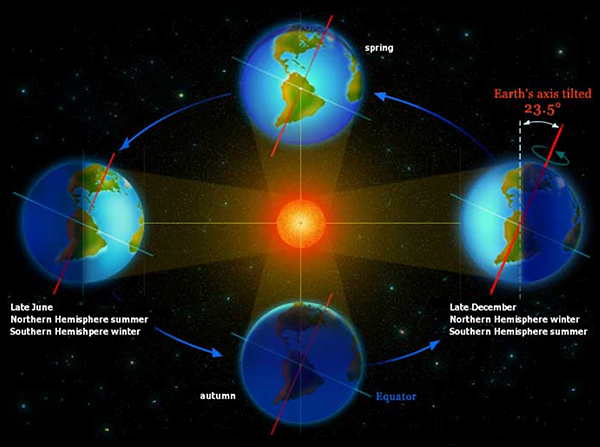
What evidence is there of Earth’s revolution? Describe this idea.

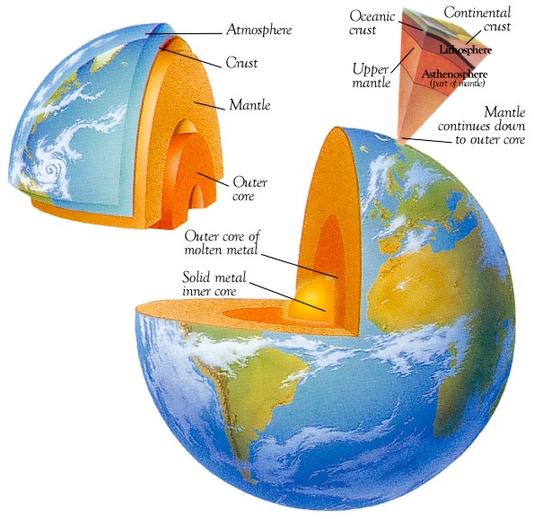
**Parallax. Apparent shift in position of nearby stars relative to distance stars as a consequence of Earth’s movement in its orbit.**

What creates the Earth’s seasons?

**Earth’s tilt and revolution**

**Whichever hemisphere is pointed towards the sun will experience summer because they are receiving more direct sunlight**



**3) Earth’s Structure**

The Nebular Hypothesis states that early Earth’s internal structure was uniform, but that its characteristics were changed by the addition of heat from:

a) **Meteorite impacts.**

**b) Weight of Layers compressed Earth’s interior**

**c) Decay of radioactive isotopes.**

-Earth’s internal materials segregated by chemical composition into several layers:

\*Use page 209 – 210 to fill out the table below

|  |  |  |  |
| --- | --- | --- | --- |
| **Layer** | **State** | **Depth from Surface (km)** | **Composition** |
| Crust |  |  |  |
| Mantle |  |  |  |
| Outer Core |  |  |  |
| Inner Core |  |  |  |

Made of mostly hydrogen

* Solar wind sends protons and electrons to earth and the collisons of these charged particles is what causes the northern lights, these particles are usually deflected by the earths margnetic field but it is weaker at the poles and therefore ad some enter and collide with gas particles, the collisions emit light that we see as the norther lights

\*\*\*\*explore NASA’s website on the sun solarsystem.nasa.gov/planets/sun/facts

It has enough nuclear fuel to stay as it is now for another 5 billion years and then it will turn into a red giant

\*\*method to measure the diameter of the sun

**The Earth** (no specific chapter in the textbook)

\*\*\*\*Ways to determine volume, density, shape and circumference etc.

Rotation or eath and revolution of earth

Variations in day length

**15.4 The Moon**

How was the moon formed?

* Collision between a Mars sized body and a youthful, semi molten Earth about 4.5 billion years ago.
* Some of the debris from the collision gradually combined to form the moon

\*\*\*\*\*Insert Figure 15.22

¼ the diameter of Earth, 1/6th the gravity of earth

Phases – oreo activity pawnees school worksheet

* At points we see both the sunlight portion and shadowed portion

New moon – moon is positioned between the earth and the sun. The entire illuminated portion is on the backside of the moon, the half we cannot see

Full moon – the earth moon and sun are in alignment just like a new moon but the moon is on the opposite side of the earth so we see the sunlight part

First quarter and third quarter (half moon) – moon is at a 90 degree angle to earth and sun. We are seeing half the sunlight and half shadowed

Crescent – less that half illuminated

Gibbous – more than half illuminated

Waxing means growing, waning means shrinking

* Why the earth doesn’t block sunlight from reaching the moon (full moon) because the moons orbit about the earth is about 5 degrees off from the earth sun orbital plane
* At some special times during the year the earh moon and sun do line up. When the moon blocks the sun it is called a solar eclipse can only happened during new moon phase. When the earth casts a shadow on the moon it is called a lunar eclipse and can only happen during a full moon. Roughly 4 – 7 eclipses happened in a year but most are minor or partial

Moons orbit takes 29.5 days

Relate moons to tides

* Has to do with the gravitational forces of the sun and moon
* Ocean water is kept at equal levels because of the balance between gravity and centrifugal force
* The moons gravitational forces are strong enough to disrupt this balance by accelerating the water towards the moon this causes the water to bulge. As the earth and moon rotate the bulge also moves. Where bulges occur are high tide and therefore other areas are low tide
* Water on the side of earth facing away from the moon also bulges but for a different reason, the earth and moon revolve together around a common fravitational center between them. Because the centrifugal force is greater than the moons gravitational pull ocean water on the opposite side bulges (example: yu swing a heavy object wwaround as you rotate, you have to lean back to compensate so the center of mass is between you and the object. Gravity is like the rope and the centrifugal keeps them apart)
* The sun can have a similar effect but not as great as the moon because it is further away
* When the sun lines up with the moon and earth the tidal effect is increased (spring tides, not for season bu springing up of water)
* First and third quarter not as high as usual (neap tides)
* When moon is closer the tides are higher and vice versa
* Tides occur twice a day high tides are 24h 50 m apart
* Tides can also be affected by moon angular height above the equator, local geography of the coastline, topography of the ocean floor, depth of the water,
* Average tide is 1 meter
* Bay of fundy – unique shape (funnel), becomes narrower and shallower thereby forcing the water higher up onto the shore

Pros and cons of space exploration (four corners, agreement line, yes/ no and convince them to come to the other side.