Agenda

- Project Ideas due today
- No Class next Thursday (10/23)
- Discuss grades
- Ch. 6 Moon
- How to work a telescope

Chapter 6

The Moon

The Earth's Moon

- Earth's nearest neighbor is space
- Once the frontier of direct human exploration
- Born in a cataclysmic event into an original molten state, the Moon is now a dead world – no plate tectonic or volcanic activity and no air
- Suffered early impact barrage
- Plays major role in eclipses and tides

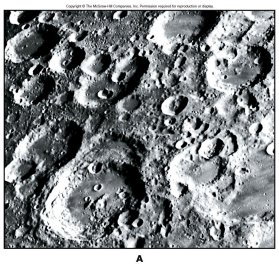
The Moon

– Moon is 1/4 the Earth's diameter
– Gravity is 1/6 as strong
– A place of "magnificent desolation" – shapes of gray without color

Surface Features

- Surface divided into two major regions
  – ***Highlands*** – Bright rugged areas composed mainly of anorthosite (a rock rich in calcium and aluminum silicates) and pitted with craters
  – ***Maria*** – Large, smooth, dark areas surrounded by highlands and composed primarily of basalt (a congealed lava rich in iron, magnesium, and titanium), which is more dense than anorthosite

Craters



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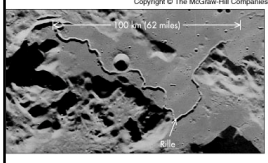
- ***Craters –*** circular features with a raised rim and range in size from less than a centimeter to a few hundred kilometers – some of the larger craters have mountain peaks at their center

Rays

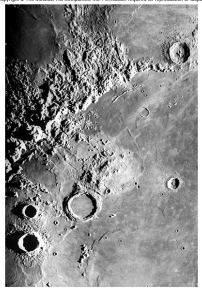
- Long, light streaks of pulverized rock radiating away from many craters and best seen during full Moon

Rilles



- Lunar canyons carved either by ancient lava flows or crustal cracking

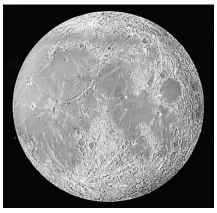
"Magnificent Desolation"



Origin of Lunar Surface Features

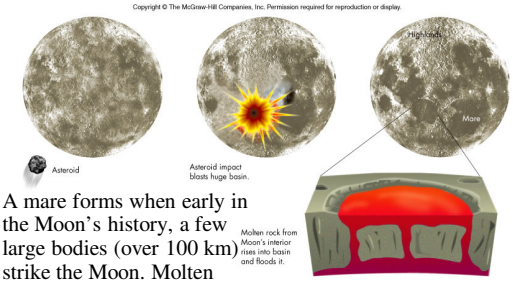
- Nearly all lunar features (craters, maria, rays) are the result of impacts by solid bodies early in the Moon's history
- A circular crater forms when a high-velocity projectile disintegrates upon impact in a cloud of vaporized rock and fragments that blast a hole in the surface

Origin of Lunar Surface Features



- The highlands are the result of the very intense bombardment by solar system bodies soon after the Moon formed and created a solid surface

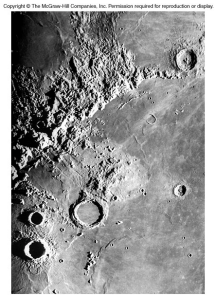
Formation of Maria



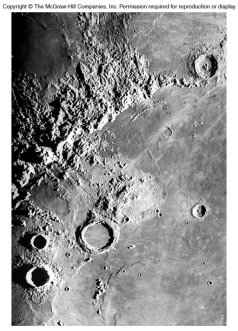
- A mare forms when early in the Moon's history, a few large bodies (over 100 km) strike the Moon. Molten material floods the newly formed lunar depression and eventually congeals

Structure of the Moon

- The Moon lacks the folded mountain ranges and variety of volcanic peaks seen on Earth
- Lack of activity due to Moon cooling off much faster than Earth
  - Moon's higher surface-to-volume ratio (relative to Earth) allows heat to escape from it faster
  - Being much less massive than the Earth, the Moon also has a smaller source of radioactive material to supply heat



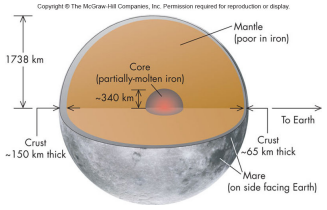
The Interior of the Moon



- Interior (including crust) studied by seismic detectors set up on Moon by astronauts – essentially found to be inactive and has simpler structure than Earth's

The Interior of the Moon - Regolith

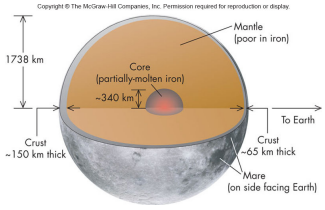
- Surface layer is shattered rock chunks and powder (from repeated impacts) forming a ***regolith*** tens of meters thick



- Regolith is basaltic in maria and anorthostic in highlands
- Regolith may extend to several hundred meters in some places

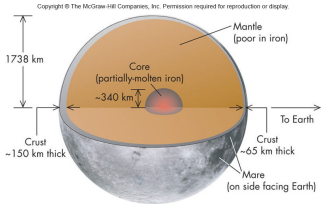
The Interior of the Moon - Crust

- Average thickness of 100 km, although crust is thinner on side that faces Earth
- Reason for asymmetry is not clear, but may be related to the difference in the Earth's gravitational force across the Moon



- Very few maria exist on side of Moon away from Earth
- Crust is composed of silicate rocks rich in aluminum and poor in iron

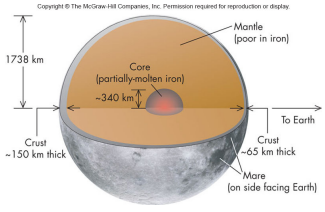
The Interior of the Moon - Mantle



- Relatively thick, extending 1000 km down
- Probably rich in olivine
- Appears too cold and rigid to be stirred by the Moon's feeble heat

The Interior of the Moon - Core

- The Moon's low average density (3.3 g/cm^3) tells us interior contains little iron
- Some molten material may be below mantle, but core is smaller and contains less iron and nickel than Earth's



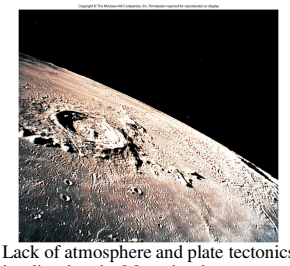
- The relatively cold Moon interior, low iron/nickel content, and slow rotation imply no lunar magnetic field – found to be the case by the Apollo astronauts

Lunar Atmosphere

- Moon's surface is never hidden by lunar clouds or haze, nor does reflected spectrum show any signs of gas and hence no winds
- Lack of an atmosphere means extreme changes in lunar surface temperature from night to day

Lunar Atmosphere

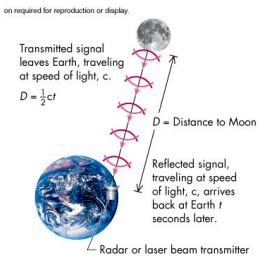
- No atmosphere for two reasons
  - Lack of volcanic activity to supply source of gas
  - Moon's gravitational force not strong enough to retain gases even if there was a source



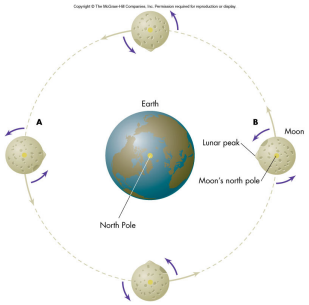
- Lack of atmosphere and plate tectonics implies that the Moon has been relatively unchanged for billions of years and will continue to be so into the foreseeable future

Orbit and Motion of the Moon

- The Moon's orbit around the Earth is elliptical with an average distance of 380,000 km and a period of 27.3 days relative to the stars
- Determining the Moon's distance can be done with high precision by bouncing a radar pulse or laser beam off the Moon

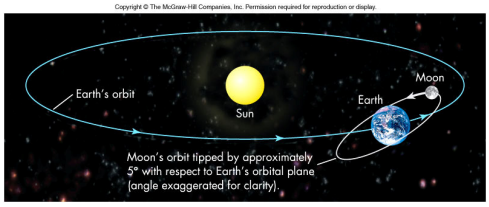


Synchronous Rotation



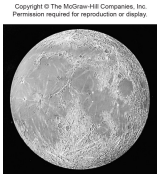
- The Moon keeps the same face toward the Earth as it orbits
- The fact that the Moon rotates at the same rate as it orbits the Earth is called s***ynchronous rotation***

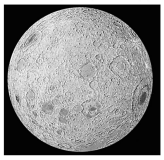
The Moon's Orbit



- The Moon's orbit is tilted about 5° with respect to the ecliptic plane
- It is also tilted with respect to the Earth's equator – very unlike most of the moons in the solar system

Something's Different…





- The Moon is also very large relative to its central planet – again unlike most of the other moons in the solar system
- These oddities indicate that the Moon formed differently from the other solar system moons!

Lunar Formation Hypotheses

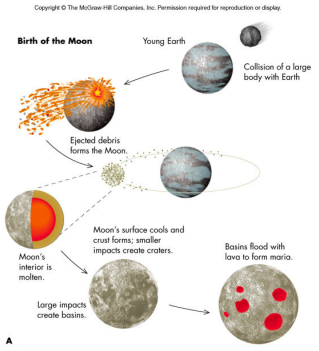
- Before Apollo missions, three hypotheses of the Moon's origin:
  - Moon originally a small planet orbiting the Sun and was subsequently captured by Earth's gravity during a close approach (***capture theory***)
  - Earth and Moon were twins, forming side by side from a common cloud of gas and dust (***twin formation theory***)
  - The Moon spun out of a very fast rotating Earth in the early day of the Solar System (***fission theory***)

Lunar Formation Hypotheses

- Each of these hypotheses gave different predictions about Moon's composition:
  - In capture theory, the Moon and Earth would be very different in composition, while twin theory would require they have the same composition
  - In fission theory, the Moon's composition should be close to the Earth's crust
- Moon rock samples proved surprising
  - For some elements, the composition was the same, but for others, it was very different
  - None of the three hypotheses could explain these observations

The Large Impact Hypothesis

- The new Moon formation hypothesis:
  - Moon formed from debris blasted out of the Earth by the impact of a Mars-sized body
  - Age of lunar rocks and lack of impact site on Earth suggests collision occurred at least 4.5 billion years ago



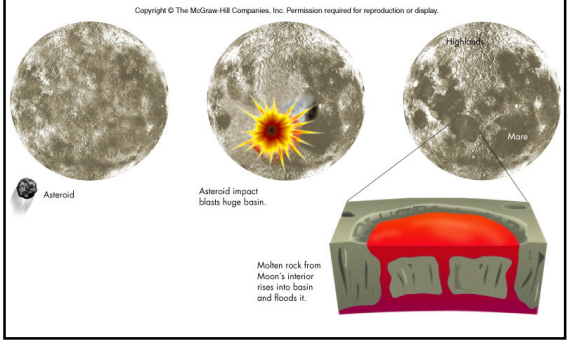
The Large Impact Solution

- This "large impact" idea explains:
  - The impact would vaporize low-melting-point materials (e.g., water) and disperse them explaining their lack in the Moon
  - Only surface rock blasted out of Earth leaving Earth's core intact and little iron in the Moon
  - Easily explains composition difference with Earth
  - The splashed-out rocks that would make the Moon would more naturally lie near the ecliptic than the Earth's equatorial plane
  - Earth's tilted rotation axis is explained

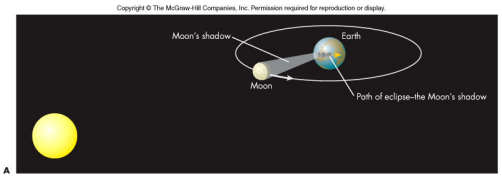
Lunar Surface Formation

- As Moon's surface solidified, stray fragments from original collision created craters that blanket highlands
- A few of the larger fragments created the large basins for the maria to form
- By the time the maria filled with molten material and solidified, little material was left for further lunar bombardment – thus the smooth nature of the maria

Lunar Surface Formation

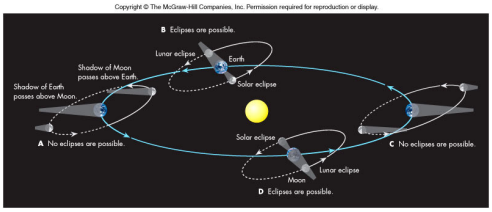


Eclipses



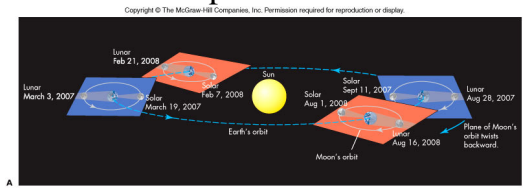
- An ***eclipse*** occurs when one astronomical body casts its shadow on another
- Observers on Earth see two types of eclipses:
  - Lunar eclipse – Earth's shadow falls on Moon
  - Solar eclipse – Moon's shadow falls on Earth

Rarity of Eclipses



- Because of the Moon's tilt relative to the ecliptic, eclipses will not occur at every new and full Moon
- Twice a year the Moon's orbit will pass through the Sun giving the possibility of an eclipse – these times are called ***eclipse seasons***

Eclipse Seasons

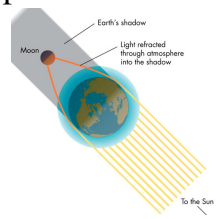


- Since the Moon's orbit tilts nearly in the same direction through the year, twice a year the Moon's orbit will pass through the Sun giving the possibility of an eclipse – these times are called ***eclipse seasons***
- When a solar eclipse occurs at new Moon, conditions are right for a lunar eclipse to occur at the full Moon either before or after the solar eclipse

Viewing an Eclipse

- Lunar eclipses can be seen from anywhere on Earth as long as the Moon is above the horizon, while an observer must be in the path of the Moon's small shadow to see a solar eclipse

What a Lunar Eclipse Looks Like



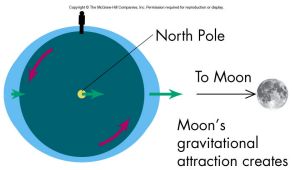
- In a total lunar eclipse, the Earth's shadow takes about an hour to cover the Moon
- At totality, the Moon generally appears a deep ruddy color
- The color of the eclipsed Moon is caused by Earth's atmosphere scattering out most of the blue in sunlight and bending the remaining reddish light at the Moon

What a Solar Eclipse Looks Like

- Hardly noticeable at first, at totality, a solar eclipse will give the appearance of nightfall
- Solar corona is also evident at totality

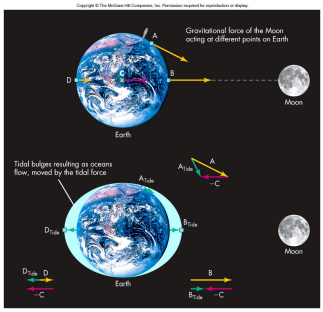
Tides

- The Moon exerts a gravitational force on the Earth that is stronger on the side closest to the Moon and weakest on the far side
- This difference in force from one side of an object to the other is called a ***differential gravitational force***



Tides

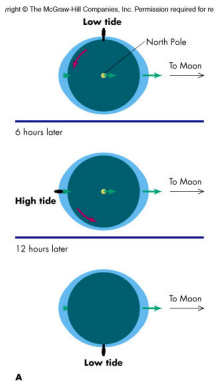
- This differential force draws water in the ocean into a ***tidal bulge*** on the sides facing and opposite the Moon



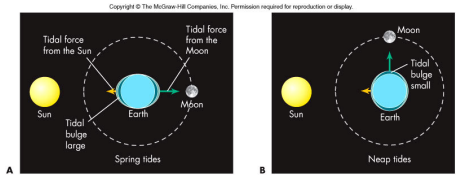
Tides

- Earth's rotation leads to two high/low tides per day

B Low tide

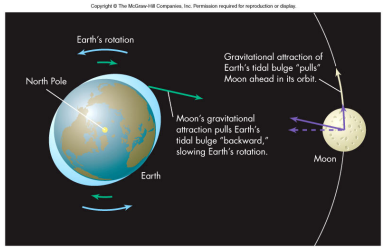


Spring and Neap Tides



- When the Sun and Moon line up (new and full Moon), abnormally large ***spring tides*** occur
- With the Moon at first or third quarter, the so-called ***neap tides*** occur, with tides not as extreme as normal tides

Tidal Braking



- Tides create forces that slow the Earth's rotation and move the Moon farther away – ***tidal braking***
- Tidal braking caused the Moon's synchronous rotation

Moon Lore

- Folklore filled with stories concerning the powers of the Moon over humans
  - Claims that the Moon triggers social behavior – hence the word "lunatic"
  - Claims the full Moon responsible for accidents, murders, etc.
  - No scientific backing for these claims
- Some "Moonisms" have a touch of truth
  - "Once in a blue Moon", meaning a rare event, may be related to an unusual atmospheric effect in which the Moon appears blue
  - "Harvest Moon", the full Moon nearest in time to the autumn equinox, rises in the east at sunset giving farmers additional light for tending to crops