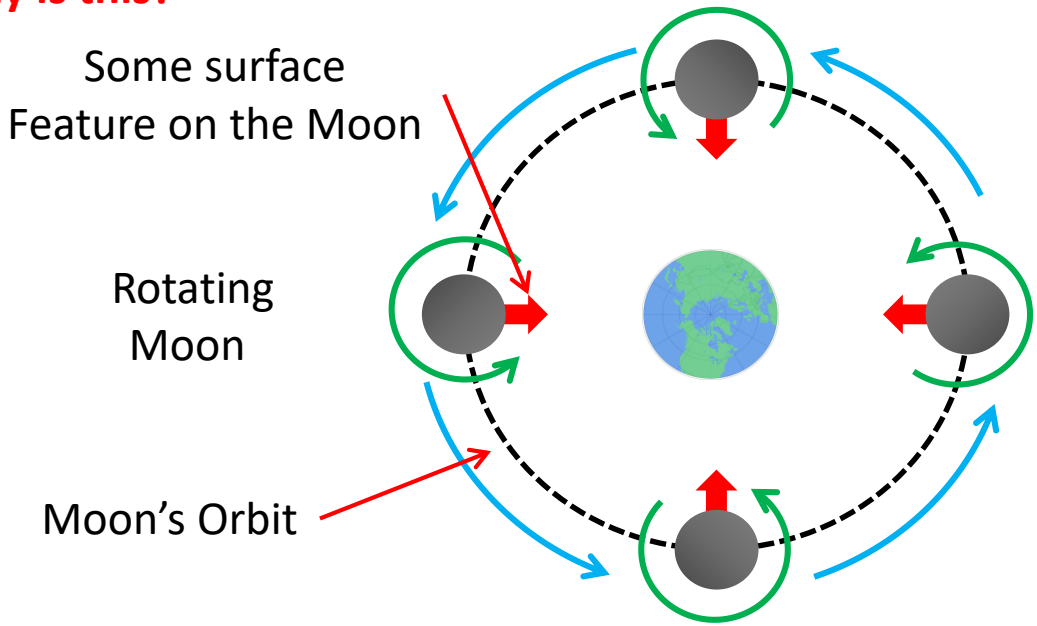
The Moon & Mercury: Dead Worlds

There are many similarities between the Moon and Mercury, and some major differences – we'll concentrate mostly on the Moon.

Appearance of the Moon from the Earth

We've already discussed the lunar phase cycle and eclipses, but have you ever noticed that **the features that we can see on the Moon never change**.

Why is this?



The Moon is locked into a **Synchronous Rotation State**, where

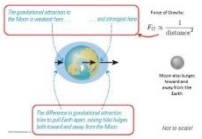
Rotation Period = Orbital Period

Appearance of the Moon from the Earth

We'll see that almost all of the moons in the Solar System are locked into synchronous rotation . . . **What causes this – is it just an accident? No.**

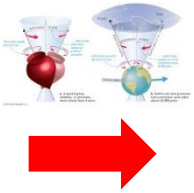
Tidal Forces (some of this is from Chapter 4):

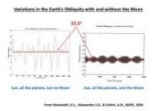
Tides refer to the difference between the gravitational force on one side of an object to the force on the other side.



The tidal force of the Moon on the Earth Causes:

- The Earth's oceans to rise and fall twice a day as the Earth rotates through the tidal bulge.
- The Earth's **Spin Axis to precess** with a period of 26,000 years.
- The Obliquity (tilt) of the Earth's Spin Axis to **not vary** too far from 23.5° (otherwise, our seasons could change drastically!)



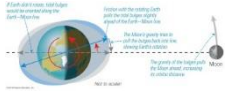


The tidal force of the Earth on the Moon Causes:

- The Moon's rotational period to slow until it matches its orbital period, i.e. synchronous rotation

(What about this? (LC))

As a system, the tidal interaction also causes the Earth's rotation to slow and the moon's orbit to increase in size. **This will last until the rotational periods of both the Earth and Moon are synchronized with the Moon's orbital period.**



Surface Features of the Moon (and Mercury)

The front side Moon is the only celestial object on which you can see surface features with the naked eye. Even a pair of binoculars reveals a lot of detail.

Two types of Lunar Terrain:

1. **Highlands:**
   - Heavily cratered areas that are lighter in color with craters of all sizes.
   - Lunar mountains are boundaries between craters

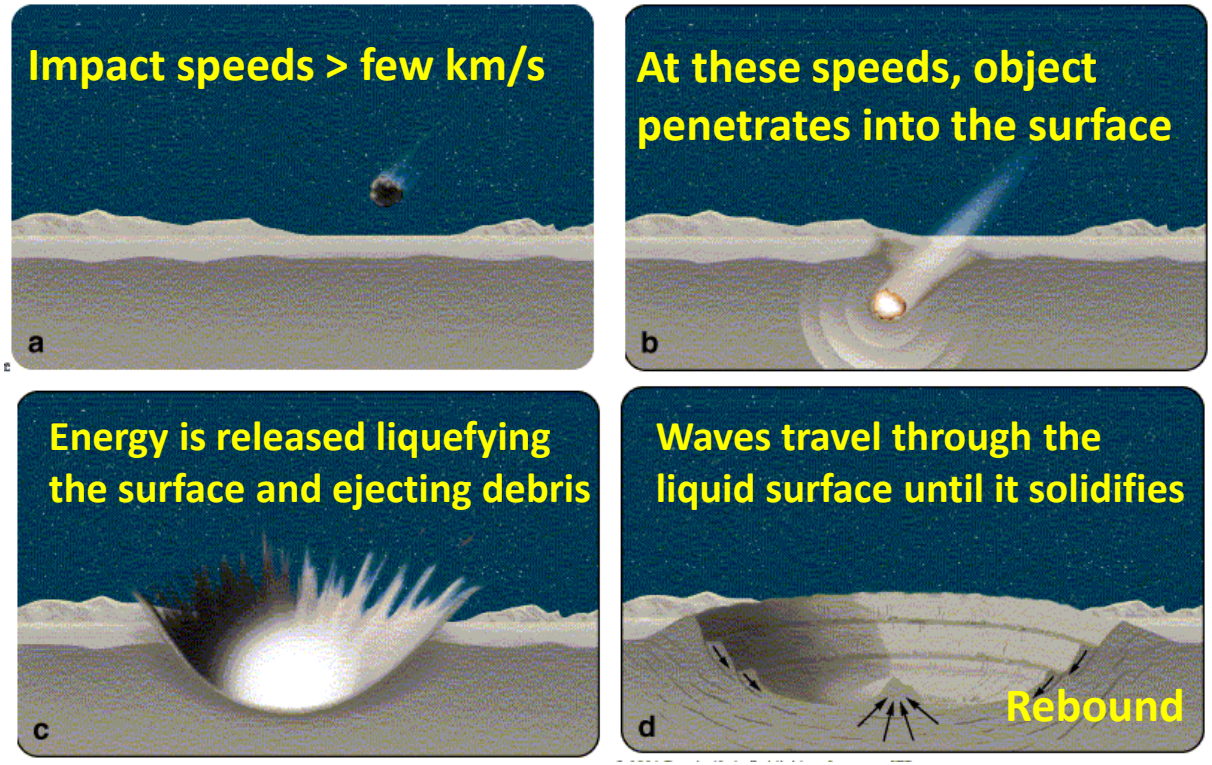
2. **Maria ("Seas"):**
   - Large dark areas with relatively few craters
   - Formed when lava flowed through the crust to fill basins.
   - None on the back side of the Moon – it has a thicker crust

Craters are the dominant feature on all solid bodies in the Solar System.

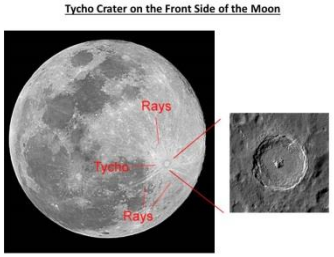
How are craters formed? (LC)

Until the 1950's, it was believed that craters on the Moon were caused by volcanoes, like most known craters on Earth at that time. **During the 1950's and 60's, it was realized that all of the craters on the Moon are caused by Impacts.**

Formation of Impact Craters



Compare to Tycho



A Really Important Question:

- If the Moon was hit by all these bodies and is covered by craters, **wouldn't the Earth have been hit as well with even more energy?**
- Would the atmosphere of the Earth act as a shield preventing impacts?
- Only from the smallest objects. . . **So, where are the craters on the Earth?**
- **They're here, but plate tectonics and erosion destroys them.**

More on Craters

What else can craters tell us? (LC)

If the rate at which craters form is fairly constant, the amount of cratering on a surface indicates its relative age: i.e.

Lots of Craters → **Older Surface**

Few Craters → **Younger Surface**

But this is only relative age. **How do we measure the actual age of the Moon?**

Radiometric Dating:

If a sample of rock contains a radioactive element that decays with a known half life into another element, measuring the fractions of the two elements determines the time since the rock solidified – *provided that the rock has remained a solid*, e.g.

Original Rock

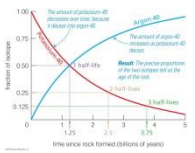
Potassium-40

Potassium-40 decays to Argon-40 with a half life of 1.25 billion years

Rock Now

Argon-40

Potassium-40



This has been used to date rocks on Earth, from the Moon, and Meteorites.

Maria rocks: 3.1 to 3.8 billion years Highland rocks: 4.0 to 4.4 billion years

The Origin of the Moon

The Earth/Moon system is unique in our solar system. The Earth is the only terrestrial planet with a large moon. **Where did it come from?**

Any reasonable theory on lunar origin must satisfy three constraints:

1. **The Size of the Moon**. The process must be able to produce a large body orbiting the Earth.

2. **The different average densities of the Earth and Moon**:

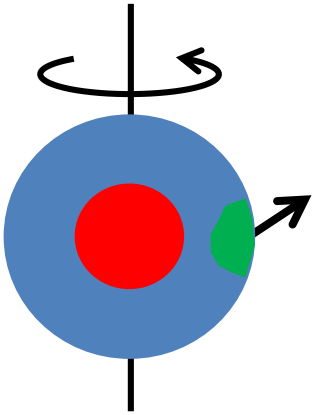
$$\rho_{\text{moon}} \sim 3.4\ g/cm^3 \text{ (}\textit{similar to Earth's mantle}\text{)}$$
$$\rho_{\text{Earth}} \sim 5.2\ g/cm^3$$

3. **The chemical composition of the Moon is similar to the Earth**, but a little different. One difference is that **The Moon is very "dry," i.e. it is lacking in volatiles (e.g. H_20, CO_2, etc.).** This was learned from analyzing moon rocks returned by the Apollo missions.

The Origin of the Moon

Over the years, **several theories** have been proposed for the Moon's origin:

The Fission Theory: the Moon "spun off" an already differentiated Earth that had very high spin.



Explains the different densities and similar chemistries.

But what happened to the high rotation rate? The Earth could not have slowed down to its present slow rotation rate by now.

The Co – Accretion Theory: The Earth and the Moon formed at the same time and place from the same material.

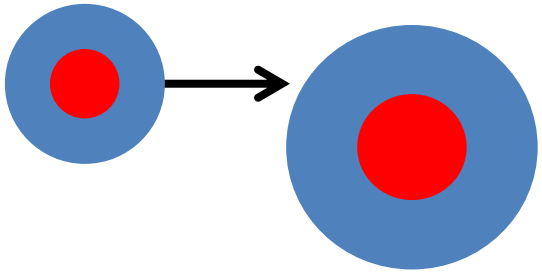
Explains similar chemistries.
But, why are the densities so different?

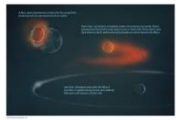
The Capture Theory: the Moon formed elsewhere in the solar system and was gravitationally captured by the Earth.

Explains different densities, but is very unlikely for such a large body.

The Origin of the Moon

The Giant Impact Theory: Earth formed alone and differentiated. Later, it was struck in a glancing collision by a Mars – sized object that had also differentiated.





Much of the ejected mantle and crust material would go into orbit around the Earth and quickly coalesce to form the Moon

How well does this idea account for the constraints?

- The Moon is made mostly of mantle and crust material, so it **should have a lower density.**
- The impact would evaporate volatiles, so **the Moon should be "dry."**
- The Moon is made of mostly Earth mantle and crust material, so the Earth and Moon **should have similar chemistries.**
- This process is dynamically possible; **collisions happened all the time.** Also, this likely produced the 23.5^{o} tilt of the Earth's spin axis, the obliquity.

As of now, this is the leading theory on the origin of the Moon, and stands as the major scientific result of the Apollo missions.

(2 **LC**)