The Solar System
- One star
- Planets
- Asteroids
- Comets
- Kuiper Belt Objects (KBOs)
- Oort Cloud
- Space Debris

Solar System Today (Not to Scale)

Inner Planets, Orbits to Scale

Inner Planets, Sizes to Scale
Top Row: Earth, Venus
Bottom Row: Mars, Mercury, the Moon

Planets, Sizes to Scale
- Top Row: Jupiter & Saturn
- Middle Row: Uranus & Neptune
- Bottom Row: Earth, Venus, Mars, Mercury, & the Moon

Planets with the Sun, Sizes to Scale
How should we categorize the objects in the Solar System?

What exactly is a planet?

1. It orbits the Sun.
2. Has enough mass so that it is round
3. It has “cleared the neighborhood”

- Pluto & Ceres satisfy #1 and #2, but not #3!
- Pluto: other Kuiper Belt Objects
- Ceres: other Asteroids

Planets & Dwarf Planets

New “Official” Definition

- Terrestrial Planets (those like Earth)
  - Mercury
  - Venus
  - Earth & Moon
  - Mars
- Jovian Planets (Like Jupiter; gas giants)
  - Jupiter
  - Saturn
  - Uranus
  - Neptune
- Dwarf Planets, including Pluto and Ceres

Terrestrial Planets

Terrestrial comes from Latin “terra” meaning “earth”

Mercury, Venus, Earth, and Mars have some similar features:

- Small mass
- High Density
- Surface features
- Fewer moons
- No ring systems
- Thinner atmospheres

Mercury’s Relative Size

<table>
<thead>
<tr>
<th>Moon</th>
<th>Io</th>
<th>Titan</th>
<th>Ganymede</th>
<th>Callisto</th>
<th>Europa</th>
<th>Titania</th>
<th>Triton</th>
<th>Pluto</th>
</tr>
</thead>
<tbody>
<tr>
<td>3476 km</td>
<td>3642 km</td>
<td>5150 km</td>
<td>3,000 miles</td>
<td>4806 km</td>
<td>3138 km</td>
<td>1580 km</td>
<td>2300 km</td>
<td>4806 km</td>
</tr>
</tbody>
</table>

The Largest Moons and Smallest Planets
Are Jovian planets all alike?

- Jovian planets (not gas giants!)
  - Better name: liquid giants (Jupiter & Saturn) or ice giants (Uranus & Neptune)
  - Large mass (about 15x-300x mass of Earth)
  - Hydrogen-rich composition
  - Low density (1/3rd to 1/7th of Earth)
  - Lots of moons, ring systems

Orbits in the Solar System

- Planets all **revolve** (orbit) around the Sun in the same direction
- Planets mostly **rotate** (spin) in the same direction on their axes
  - Exceptions: Uranus & Venus
- Orbital planes are close: within 5° of Earth's orbital plane (the ecliptic)
- Spin planes are close: all within 30° of the Sun's equator (with the exception of Uranus)

Protoplanetary Disks

- More Disks

More Disks
Chemicals in the Planets

- Sun’s composition: about 3/4 Hydrogen, 1/4 Helium, with roughly 2% other stuff
- Earth is very different!
- Jupiter & Saturn are more similar…

Clues to Formation

- Patterns of Motion
- 2 types of planets
  - Terrestrial & Jovian
- Asteroids and Comets
- Exceptions to the Rules

Early Solar System

- The young Sun probably had a disk of gas & dust: the Solar Nebula
- Small cores in the disk (planetesimals) grow through accretion
- Temperature is warmer as you get closer to the center (where the Sun is!)

Collisions dominated the early solar system

- dust collects together into planetesimals
- planetesimals collect together into protoplanets
- Protoplanets gather up left over debris and became planets

Predictions from the Solar Nebula Theory

- Planet orbits should fall roughly in one plane
- Orbit and spin directions should be mostly the same
- Planets should have roughly the same age as their star
Differentiation in the Solar Nebula

- Material forms clumps according to temperature
- Only high-density elements can form clumps at high temperatures

Cooler Temperatures

Temperature and Formation of the Solar System Lecture-Tutorial: Pg. 111-112

- Work with a partner or two
- Read directions and answer all questions carefully. Take time to understand it now!
- Come to a consensus answer you all agree on before moving on to the next question.
- If you get stuck, ask another group for help.
- If you get really stuck, raise your hand and I will come around.

Explanations from Solar Nebula Theory:

- Rocky inner planets, gaseous outer planets
- Common orbital and spin directions
- Common age of planets & star

- Jupiter is very massive, gravitational force prevents a planet forming between Mars & Jupiter: Asteroid belt!
- Comets & Kuiper Belt: leftover planetesimals!

Unsolved Problems:

- How fast do Jovian planets form? How fast does the disk get cleared out?
- Does the disk cool slowly or rapidly?
- What about orbital migration?
- Why does Venus spin backward? Why is Uranus tilted on its side?