Lesson 5 - Introduction to the Solar System

READING ASSIGNMENT

- Chapter 6.1: An Inventory of the Solar System
- Chapter 13.1: The Discoveries of Uranus and Neptune
- Chapter 14.3: Beyond Neptune
- Chapter 2.6: The Dimensions of the Solar System
- Chapter 6.2: Measuring the Planets
- Chapter 6.3: The Overall Layout of the Solar System
- Chapter 6.4: Terrestrial and Jovian Planets
- Chapter 6.5: Interplanetary Matter
- Chapter 6.6: Spacecraft Exploration of the Solar System
  - Discovery 6-1: Gravitational “Slingshots”
  - Discovery 8-1: Lunar Exploration

SUMMARY OF DISCOVERY OF THE SOLAR SYSTEM

Read Chapter 6.1.

Pre-History

Earth

The sun and the moon

The five naked-eye planets: Mercury, Venus, Mars, Jupiter, and Saturn

Comets and meteors

17^{th} Century

Galileo’s discovery of Jupiters four large moons: Io, Europa, Ganymede, and Callisto (1609)

Huygen’s discovery of Saturn’s rings and Saturn’s large moon Titan (1655)

18^{th} Century

Herschel’s discovery of Uranus (1781)

19th Century

Piazzi's discovery of Ceres (1801)

Ceres is the first discovered and largest member of the asteroid belt. It and dozens of other asteroids were considered to be planets for more than half a century, after which they became too numerous and were all demoted and reclassified as asteroids. However, Ceres was once again promoted and reclassified as a dwarf planet in 2006.

Asteroid belt

We continue to discover new asteroids, both in and out of the asteroid belt, to the present day.

Planetary moons

We continue to discover new moons around Jupiter, Saturn, Uranus, and Neptune, as well as around dwarf planets, Kuiper belt objects, and even asteroids to the present day.

Adams' and Le Verrier's predictions of the existence of Neptune and its subsequent discovery (1846)

Neptune's existence was predicted mathematically from gravitational perturbations of Uranus's orbit. British Adams and French Le Verrier share credit for the subsequent discovery (although Le Verrier probably deserves more credit than Adams). Neptune's large moon Triton was discovered weeks later.

20th Century

Tombaugh's discovery of Pluto (1930)

Pluto is the first discovered but possibly not the largest member of the Kuiper belt. It was considered to be a planet for 76 years, but was demoted and reclassified as a dwarf planet after the discovery of larger and more massive Eris.

Planetary rings

In addition to around Saturn, rings were discovered around Jupiter, Uranus, and Neptune.

Kuiper belt

The discovery of the Kuiper belt has only just begun!

21st Century

Brown's discovery of Sedna (2003)

At 526 AU, the semi-major axis of Sedna's orbit is more than six times that of any known Kuiper belt object, which puts it in a class of its own. It is also the largest trans-Neptunian object that has not yet been classified as a dwarf planet.

Brown's discovery of Eris (2005)

Eris is possibly the largest member of the Kuiper belt. Classified as a dwarf planet in 2006, it forced Pluto's demotion and reclassification as a dwarf planet.

Kuiper belt objects Makemake (2005) and Haumea (2004) promoted and reclassified as dwarf planets (2008)

SUMMARY OF EXPLORATION OF THE SOLAR SYSTEM

Read Chapter 6.6, Discovery 6-1, and Discovery 8-1.

Missions in bold face are still active or were recently active.

Locations where we have successfully flown spacecraft.

- The moon
- Mercury
  - *Mariner 10* (1974)
- Venus
  - *Mariner 2* (1962)
  - *Mariner 5* (1967)
- Mars
  - *Mariner 4* (1965)
  - *Mariner 6* (1969)
  - *Mariner 7* (1969)
- Jupiter
  - *Pioneer 10* (1973)
  - *Pioneer 11* (1974)
  - ***Voyager 1*** (1979)
  - ***Voyager 2*** (1979)
  - ***New Horizons*** (2007)
- Saturn
  - *Pioneer 11* (1979)
  - ***Voyager 1*** (1980)
  - ***Voyager 2*** (1981)

- Uranus
  - ***Voyager 2*** (1986)
- Neptune
  - ***Voyager 2*** (1989)
- Pluto
  - ***New Horizons*** is expected to fly by Pluto in 2015.
- Comets
  - Many spacecraft have now flown through the tails of many comets, beginning with Halley's comet in 1985. In 2003, *Stardust* flew through the tail of comet Wild 2 and in 2006 returned a sample to Earth (although not completely successfully—the parachute failed to deploy).
- Asteroids
  - Many spacecraft have now flown by many asteroids, beginning with *Galileo's* flybys of the asteroids Gaspra (1991) and Ida (1993) on its way to Jupiter. Ida was discovered to have a small moon, which was named Dactyl.

Locations where we have successfully put spacecraft into orbit around.

- The moon
- Mercury
  - ***Messenger*** (2011)
- Venus
  - Soviet *Venera 9* (1975)
  - Soviet *Venera 10* (1975)
  - *Pioneer Venus Orbiter* (1978)
  - Soviet *Venera 15* (1983)
  - Soviet *Venera 16* (1983)
  - *Magellan* (1990)
- Mars
  - Soviet *Mars 2* (1971)
  - Soviet *Mars 3* (1971)
  - *Mariner 9* (1971)
  - Soviet *Mars 5* (1973)
  - *Viking 1 Orbiter* (1976)
  - *Viking 2 Orbiter* (1976)

  - *Mars Global Surveyor* (1997)
  - ***Mars Odyssey*** (2001)
  - European ***Mars Express Orbiter*** (2003)
  - ***Mars Reconnaissance Orbiter*** (2006)

- Ceres
  - ***Dawn*** is expected to enter orbit around Ceres in 2015.

- Jupiter
  - *Galileo* (1995)
  - ***Juno*** is expected to enter orbit around Jupiter in 2016.

- Saturn
  - ***Cassini*** (2004)

- Asteroids
  - ***Dawn*** entered orbit around Vesta in 2011. (***Dawn*** will leave Vesta for Ceres in 2012.)

Locations where we have successfully launched spacecraft/probes into the atmospheres.

- Venus
  - Soviet *Venera 4* (1967)
  - Soviet *Venera 5* (1969)
  - Soviet *Venera 6* (1969)
  - *Pioneer Venus Large Probe* (1978)
  - *Pioneer Venus North Probe* (1978)
  - *Pioneer Venus Night Probe* (1978)

- Jupiter
  - *Galileo Probe* (1995)

Locations where we have successfully landed spacecraft/probes.

- The moon

- Venus
  - Soviet *Venera 7* (1970)
  - Soviet *Venera 8* (1972)
  - Soviet *Venera 9* (1975)
  - Soviet *Venera 10* (1975)
  - *Pioneer Venus Day Probe* (1978)

- Soviet *Venera 11* (1978)
- Soviet *Venera 12* (1978)
- Soviet *Venera 13* (1981)
- Soviet *Venera 14* (1981)
- Soviet *Vega 1 Probe* (1985)
- Soviet *Vega 2 Probe* (1985)
- All of these melted within about an hour of landing.

- Mars
  - *Viking 1 Lander* (1976)
  - *Viking 2 Lander* (1976)
  - *Mars Pathfinder* and its rover *Sojourner* (1997)
  - *Mars Exploration Rover Spirit* (2004)
  - ***Mars Exploration Rover Opportunity*** (2004)
  - *Phoenix Mars Lander* (2008)
  - ***Mars Science Laboratory*** is expected to land and rove on Mars in 2012.
- Saturn's large moon Titan
  - *Huygens* (2004)
- Near-Earth asteroid Eros
  - This depends on your definition of successful. We purposefully crash-landed the *NEAR Shoemaker* spacecraft on Eros at the end of its mission, on Valentine's Day 2001. Not designed to survive this, it didn't. However, it continued to collect and transmit data to Earth until the very end.
- Comet Temple
  - We purposefully crashed a 770 pound probe, released from the *Deep Impact* spacecraft, into Temple on Independence Day 2005. This resulted in a magnificent explosion and a crater the size of a football field. *Deep Impact*, as well as Earth-based telescopes, studied the ejecta to better understand the composition of comets and that of the early solar system in which they formed.

Locations where we have successfully landed humans.

- The moon
  - Apollo 11 (1969)
    * Neil A. Armstrong
    * Edwin E. Aldrin
  - Apollo 12 (1969)
    * Charles Conrad, Jr.
    * Alan L. Bean

- Apollo 14 (1971)
  * Alan B. Shepard, Jr.
  * Edgar D. Mitchell
- Apollo 15 (1971)
  * David R. Scott
  * James B. Irwin
- Apollo 16 (1972)
  * John W. Young
  * Charles M. Duke, Jr.
- Apollo 17 (1972)
  * Eugene A. Cernan
  * Harrison H. Schmitt

MATH NOTES

Planetary Diameter

Read Chapter 6.2.

- D = diameter of planet
- θ = angular diameter of planet
- d = distance to planet

$$D = \left(\frac{2\pi}{360^\circ}\right) \times \theta \times d \tag{1}$$

- Note: This equation, sometimes called the "skinny triangle" equation, is only valid if θ is small.

Planetary Mass

Read Chapter 6.2.

- P = orbital period of satellite (natural or artificial)
- a = orbital semi-major axis of satellite
- M = mass of planet
- Newton's form of Kepler's Third Law tells us that:
  - P^2 is proportional to $\frac{a^3}{M}$.

- Solving for M yields:
  - M is proportional to $\dfrac{a^3}{P^2}$.
- Consider the case of Earth orbiting the sun. Then:
  - M_{sun} is proportional to $\frac{a_{\text{earth}^3}}{P_{\text{earth}^2}} = \frac{(1\ \text{AU})^3}{(1\ \text{yr})^2}$.
- Dividing this equation into the previous equation yields the following.

$$\frac{M}{M_{\text{sun}}} = \frac{(a/1\ \text{AU})^3}{(P/1\ \text{yr})^2} \tag{2}$$

- Hence, as long as M is measured in solar masses, a is measured in AU, and P is measured in years, Newton's form of Kepler's Third Law should be very easy to use.

Average Density

Read Chapter 6.2.

- ρ = average density of planet
- M = mass of planet
- V = volume of planet
- R = radius of planet (= half of diameter of planet)
- $\rho = \frac{M}{V}$
- $V = \frac{4\pi R^3}{3}$
- Hence, the following is true.

$$\rho = \frac{3M}{4\pi R^3} \tag{3}$$

Example values:

- Water, compressed gas: 1000 kg/m^3
- Rock: 2000 kg/m^3 – 3000 kg/m^3
- Iron: 8000 kg/m^3

HOMEWORK 5

Download Homework 5 from WebAssign. Feel free to work on these questions together. Then submit your answers to WebAssign individually. Please do not wait until the last minute to submit your answers and please confirm that WebAssign actually received all of your answers before logging off.

EXTRA CREDIT HOMEWORK

Write a 2-page essay on any of the missions, or related series of missions, listed above under "Summary of Exploration of the Solar System". I will grade this **optional** homework pass/fail. If you pass, I will drop your second worst homework when I average your homework grades at the end of the semester (I already drop your worst homework grade). The extra credit homework is due with the final exam.

To pass, follow these simple rules:

- The essay should be single spaced with 1.25-inch margins.
- Use 12-point Times New Roman font.
- The header should consist of a title, your name, and a single space before the beginning of the essay. Do not put spaces between paragraphs.
- The essay should run at least one line onto page three.
- Include a bibliography of your sources on page three.
- Stay on topic and don't make things up!