4. Our Solar System (Lecture 4, Chap7)

4.1-4.3 Structure of the Solar System
a. Must know the names of all planets, their relative distances from the Sun, and members in the two categories of planets.
b. Must know how terrestrial planets are different from Jovian planets: the relative size, mass, average density, composition etc.
c. Must know how Pluto is different from other planets: why Pluto does not fit either category.
d. Must know which planets have satellites.
e. Know the seven largest satellites in the solar system, their names, their parent planets, relative size, mass, average density, composition, presence of atmosphere.
f. Must know what are asteroids and comets, where they are found, and how asteroids are different from comets.
g. Must know Kepler’s third law: $P^2 = a^3$. Must know the units in the formula. Must know to which solar system objects Kepler’s third law can be applied to calculate the orbit distance or period.

4.4 Presence of Atmosphere – Escape Speed and Thermal Speed
a. Must know what factors determine whether a certain gas can be present in the atmosphere of a planet or satellite. Must be able to reason why certain planets have an appreciable atmosphere while others do not.
b. Must know the concepts of average thermal speed and escape speed and be able to use the thumb rule to find out whether a certain gas is retained in the atmosphere.

Average thermal speed of a gas at temperature $T$ is:

$$v_{th} = \left(\frac{3kT}{m}\right)^{1/2}$$

$m = \text{mass of a gas particle (kg)}$; $T = \text{temperature (K=kelvins)}$; $v_{th} = \text{average thermal velocity (m/sec)}$; $k = \text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ J/K}$

Escape speed at the surface of a planet:

$$v_{esc} = \left(\frac{2GM}{R}\right)^{1/2}$$

$M = \text{mass of the planet (kg)}$; $R = \text{radius of the planet (m)}$; $G = \text{gravitational constant} = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$.

Example: comparing capabilities of Earth and the Moon to retain a certain gas.

4.5 Composition
a. Must know how to estimate the average density.
b. Must know how to estimate roughly the composition of planets and satellites from their average density.
   Note: Average density of water = 1000 kg/m$^3$
   Average density of rock = 3000 kg/m$^3$
   Average density of metal (e.g. iron) = 13,000 kg/m$^3$
c. Must know how the surface and atmosphere compositions can be determined more accurately (also reveal Lecture 2).
   Example: how do we know that methane, but not H or O$_2$, is dominant in Titan’s atmosphere.
   Example: Europa’s surface composition

4.6 Cratering and Age
   a. Know how craters are formed.
   b. Know how we estimate roughly the age of the surface by the number of craters.
   c. Know how geological activities affect the number of craters.

4.7 Magnetic Fields
   a. Know which planets have global magnetic fields.
   b. Must know what causes a planet to have a strong magnetic field – what is dynamo.
   c. Know how the mechanisms of dynamo are different in terrestrial planets and Jovian planets.

Other: know how to determine properties of planets: orbit size, orbit period, diameter, mass, density, composition, magnetic field, internal structure.

5. The Living Earth (Lecture 5, Chap 9)
5.1 Earth’s Activity, Energy, and Greenhouse Effect
   a. Must know what are the energy sources to drive various activities on the Earth: motion of water, motion of atmosphere, reshaping of the surface, and life.
   b. Must know the nature of tidal force and what effects it produces on the Earth.
   c. Greenhouse effect:
      - Must know how Earth’s incoming and outgoing energies are balanced.
      - Must know the dominant wavelengths of solar radiation and Earth’s radiation.
      - Must know the concept of albedo (reflectance).
      - Must be able to calculate the theoretical mean surface temperature of Earth (see your homework problem).
      - Must know what is the greenhouse effect, how it affects the Earth’s surface temperature, and why such effect on temperature is critical.
      - Know what gases are greenhouse gases.
      - Understand what might be the consequence of human-caused greenhouse effect in the past century.

5.2 The Earth’s Atmosphere
1. Know the composition of the Earth’s atmosphere, and how it is different from atmospheres of other terrestrial planets.
2. Know the history and evolution of the Earth’s atmosphere.
3. Must know the stratification of the atmosphere, the temperature profile of each layer, and why so.
4. Must know how the Earth’s atmosphere protects us from short-wavelength solar radiation.
5. Know major circulation patterns in the Earth’s atmosphere, and the major mechanisms causing these patterns.

5.3 The Earth’s Internal Structure
1. Must know the layered structure of the Earth’s interior, and how it formed.
2. Know relative size, density, and rough composition of different layers: inner core, outer core, mantle, and crust.
3. Must understand why the outer core is liquid while the inner core is solid.
4. Understand how seismic waves produced in earthquakes are used to diagnose the interior structure of the Earth.
5. Must know the proofs that the Earth has a liquid core.

5.4 Plate Tectonics
1. Know what is a Pangaea, the idea of continent drift, and geological proofs.
2. Know the concepts of plate tectonics and how it works. Know the concepts of lithosphere, asthenosphere, subduction.
3. Must know what (energy source) drives plate tectonics, and be able to reason what factors lead to plate tectonics.
4. Must know how major geological features, mountain ranges, earthquakes, gulfs, etc., are produced due to plate tectonics, and where significant geological activities (like volcanoes and earthquakes) are located.
   Example: geographic location of the Everest and its continuous growth.

5.5 The Earth’s Magnetosphere
1. Must know how the Earth’s magnetic field is generated (also see Lecture 4).
2. Know the particle radiation belt - the Van Allen Belt, and how it is formed.
3. Know how the Earth’s magnetosphere protects life on Earth.
4. Understand how aurorae are produced and why they are usually seen in polar regions.
   Example: dramatic auroral display after some violent solar coronal mass ejection events.
5. Understand what is space weather, the origin of space weather, and how we may forecast space weather.

6. The Moon and Eclipses (Lecture 6, Chap 10 & 3)
6.1-2 Introduction
1. Know the general properties of the Moon: its orbit, size, mass, density, and temperature, relative to those of the Earth.
2. Must understand why there is no water and no atmosphere on the Moon.
3. Must understand effects of gravity on the Earth-moon system: what is a tidal force? How does the moon’s gravity affect Earth’s motion? How does the Earth’s gravity affect the moon’s motion?
d. Must know properties of the orbital and rotation motions of the moon. Must know what is synchronous rotation and what causes it. Understand what causes the libration, and why we see 59% of the Moon’s surface.
e. Know of unmanned and manned missions to the Moon.

6.3-5 Moon’s surface, interior, and rocks
a. Know major geological features on the Moon’s surface: highlands, maria, and craters, and the difference in surface features between the Earth-facing side and far side.
b. Must know why a large number of craters are present on the Moon but not on the Earth.
c. Know how maria formed, and what properties of the Moon can be deduced from observational facts of maria.
d. Know the structure and composition of the Moon’s interior, and how they are different from those of the Earth. Know what causes moonquakes.

6.6-7 Lunar phases and eclipses
a. Must understand the Moon’s orbital motion and what factors lead to the cyclic variations of the Moon’s phase.
b. Must be able to tell the phase of the moon, or times of moon rise and moon set relative to times of sun rise and sunset, in a given situation by using a diagram to show the relative positions of the Earth, Moon, and Sun.
c. Must understand the reasons for solar and lunar eclipses.
d. Must know around what lunar phases a solar or lunar eclipse may take place.
e. Must understand the concept of the line of nodes. Must understand why we do not see a solar eclipse and a lunar eclipse every month. Know how often solar eclipses and lunar eclipses take place.
f. Know what are total, partial, and penumbral lunar eclipses, and what are total, partial, and annular solar eclipses. Must know in what situations an observer can observe different kinds of eclipses.
g. Must understand why a solar eclipse is visible only in certain areas on the Earth, whereas a lunar eclipse can be observed by people in a hemisphere. Know qualitatively how to estimate the size of shadows and durations of the eclipses.

7. Terrestrial Planets (Lecture 7; Chap 11)
7.1-3 Introduction, positions, and motions
h. Study the data for Mercury, Venus, and Mars, in comparison with data for the Earth and moon; know the general properties of terrestrial planets in terms of size, mass, distance to the Sun, existence of atmosphere and water, and temperature and its variation.
i. Must understand the angular positions of planets in the sky. Must know the concepts of inferior planets, superior planets, conjunctions, oppositions, and greatest western and eastern elongations.
j. Know Kepler’s first law and understand the concepts of eccentricity, perihelion, and aphelion.
k. Must understand when are the best times to observe Mercury, Venus, and Mars from the Earth. Must understand what determines the apparent brightness of a planet, and why Venus is the brightest planet in the sky (Ex. 2).
l. Must understand the following phenomena: phases of planets and solar transit of planets. Must be able to estimate the angular size of planets at different phases.
m. Must know the 3-to-2 spin-orbit coupling of Mercury’s motion and what causes such coupling – compare this with the moon’s spin-orbit motion pattern.
n. Must know the concepts of prograde and retrograde rotations.
o. Understand the length of a solar day on planets with certain rotation/orbit patterns.
p. Must know the observational methods to determine the rotation velocity of a rotating planet.

7.4 Atmosphere
a. Review what conditions determine whether certain gas particles can be retained in a planet’s atmosphere.
b. Must know general properties of terrestrial atmospheres in terms of air pressure, temperature profiles, and compositions, and how they are different on Venus, the Earth, and Mars.
c. Must know evolutions of the terrestrial atmospheres. Must know what are the runaway greenhouse effect and runaway icehouse effect, and how they affect terrestrial atmospheres.
d. Must know how to calculate the mean surface temperature of a planet using the energy balance equation. Must understand the meaning of the terms in the energy equations.

\[
P_{in} = P_{out}
\]

\[
P_{in} = \frac{4\pi R_s^2 \sigma T_s^4}{4\pi d^2} \pi R^2 (1 - a)
\]

\[
P_{out} = 4\pi R^2 \sigma T^4
\]
e. Know the atmosphere circulation patterns and seasonal variations on terrestrial planets.

7.5-7 Surface, geological activities, interior, magnetic fields, missions
d. Must know characteristic surface features on terrestrial planets and major, if any, geological activities on these planets.
Example: mountains, basins, and channel-like features are present in all terrestrial planets. How did they form?
e. Must know the relative ages of terrestrial surfaces and understand why. Must know what drives geological activities and why plate tectonics are present only on the Earth.
f. Understand radar techniques to observe the surface of a planet below clouds.
g. Must know observational evidence for past and current water on Mars.
h. Know the interior structures of terrestrial planets and the moon. Know what planets have global magnetic fields and why. Must know methods to find out the interior structure of a planet.

i. Know of past, current, and future missions to terrestrial planets, and what are the scientific goals in these missions.

General: Comparatively study properties of terrestrial planets: their motions, surface features, atmospheres, evolutions, and interiors. Must know how to explain the differences and similarities in the properties of these planets (see Review of Terrestrial Planets in Lecture 7).

8. Global Change (Lecture 8, Chap 9-7)
   b. Must understand the energy balance equation; know what factors may contribute to variations in Earth’s surface temperature.
   c. Know of the history of Earth’s climate and the issue of global warming.
   d. Must know what is the solar constant. Know roughly how much variation has been observed in the solar constant, and whether this alone can account for global warming in the past century.
   e. In general, understand arguments on global change within the scope of this course.

------------- End of Review II ---------------