Astronomy 3 -Solution Set 5

1. **Describe three distinctive regions in the earth interior. How do we get detailed information on the interior of the Earth?**

   The earth interior is composed of a high-density metal core in the center which is surrounded by a medium density mantle, and a low-density rocky crust. We probe the interior of the earth with seismic waves excited by earth quakes. The precise speed and directions of all seismic waves depend on the composition, density, pressure, temperature, and phase of the material they pass through. Careful analysis of seismic waves therefore offers a very detailed picture of the earth's interior.

2. **During the 1989 Loma Pieta earth quake, AY3 students sensed an side-way shake 3 seconds before a much larger amplitude rolling motion. Based on the information that P and S waves travel at 10 and 5 km/s, determine the distance of the epicenter from Santa Cruz.**

   The side-way shake is due to the passage of the P wave whereas the rolling motion is due to the passage of the S wave. Suppose the distance betweeb the epicenter and Santa Cruz is D.

   The time needed for the P wave to travel from the epicenter to Santa Cruz is t (P wave) = D / (10 km/s)

   The time needed for the S wave to travel from the epicenter to Santa Cruz is t (S wave) = D / (5 km/s)

   The difference between the arrival of these two waves is t (S wave) - t (P wave) = 3 second.

   Using these three equations for substitutions, D / (5 km/s) - D / (10 km/s) = 3 second.

   The solution of this equation is D = 3 second / (1 / (5 km/s) - 1 / (10 km/s)) =30 km.

   The distance between the epicenter and Santa Cruz is 30 km.

3. **What are the three possible sources of heat which led to the molten interior of the Earth?**

   The earth interior is heated by accretion of planetesimals. During the infall of the planetesimals, gravitational potential energy is converted into kinetic energy which eventually turn into heat energy when the planetesimals hit the earth surface. The earth is also heated as a consequence of the differentiation process. In the interior of the earth, light materials rise to the surface while the dense materials fall to the core. Gravitational energy is converted into thermal energy. The third avenue for heat generation is through radioactive decay. During the decay of radioactive isotopes, the mass-energy contained in nuclei is converted into thermal energy.

4. **Suppose Mars turn out to have a mass and size comparable to the Moon. How would these characteristics affect the number of geological features due to each of the four major geological processes? Would Mars still be a good candidate for harboring extraterrestrial life?**

   The mass and size of the moon are smaller than those of Mars. Since neither Mars nor the moon has sufficient gravity to enhance the collisional frequency between residual planetesimals and them, we expected impact crater per unit area to remain unchanged.

   With a smaller size, the hypothetical Mars would cool off faster than the real Mars. Consequently, the interior of the hypothetical Mars would solidify, tectonic and volcanism would cease at an earlier epoch. With a smaller surface gravity, the hypothetical Mars may also lose its atmosphere at a much faster pace. In the limit of much weaker tectonic, volcanism, and erosion processes, older features on the surface is better preserved and age of the hypothetical Mars' surface is expected to be older. Since planetesimal bombardment rate decreased with time, the surface of the hypothetical Mars would be scared by more densely populated impact craters.

   Since life needs the presence of liquid water, which requires a substantial atmosphere pressure on Mars, the environment on the hypothetical Mars is more hostile to the emergence and proliferation of life.

5. **In a recent investigation to determine the age of Mars' southern hemisphere, the age of the Martian crust there was determined with radiometric dating of the surface rocks. This finding turned out to differ from the age of this region estimated from the comparison between its crater density with that of the Moon. Which technique seems to be more reliable? Which technique is more practical? Explain.**

   The radiometric dating is more reliable but the crater counting is more practical. The density of craters is not only determined by the rate of the planetesimal bombardment, but also their preservation. The bombardment rate of planetesimals depends depends on their number density at any give time and location. Although the average rate of bombardment is well estimated, the actual impact rate may fluctuate. In addition, the strength of the bombardment is determined by both the planetesimals size distribution and their impact speed. Both can vary. The impact craters may also be resurface by volcanism, tectonics, and erosion. Variations in the occurrence rates of these processes can significantly vary throughout the evolution of the planet. Thus, the age estimates based on the crater density on the surface is subject to a large degree of uncertainties. These processes generally do not significantly modify the radioactive decay of isotopes, so that the radiometric method is a more reliable approach. But the radiometric method requires sample return which is technically challenging.

6. **With its peak towering over 26 kilometers and base covering over 600 kilometers, Olympus Mons is the largest shield volcano in the solar system. Why is it not possible for such a high volcanic mountain to stand on the Earth?**

   The height and extent of the highest mountain on any planet is limited by the material strength of its lithosphere (crust) against the poll of its gravity. The Earth has a larger mass and density than Mars. Consequently, the gravity on the Earth surface is stronger than that on Mars. The mountain can be supported on the Earth is smaller than that on Mars. On a planet which is smaller than Mars, the internal heat is cooled off quickly and the volcanism is less active to produce large volcanos.

7. **There are many evidences which suggest water once flow on the surface of the Mars. What does this finding imply in the ancient atmosphere of Mars? Where did most of this water go? How does loss of water relate to the red color of the Martian surface?**

   The eroded landscape on Mars suggest that liquid water once flow on the surface of Mars. Water can only attain a liquid phase under pressure comparable to that of the Earth atmosphere. Scientists infer that the atmosphere of Mars was once much denser and warmer than it is today. Mars has a very weak magnetic field, probably because its interior cooled off very early. Unlike the Earth, there is no biological activities to provide a source of free oxygen and ozone in the atmosphere of Mars. Without a magnetosphere to trap energetic particles from the solar wind and an ozone layer to block Sun's UV radiation, the water molecules in the Martian atmosphere are vulnerable to ionization. After ionization, the light hydrogen molecules escape the pull of Mars' gravity. The remaining oxygen atoms combine with other heavy elements through oxidation processes. The most abundant compounds are oxidized iron which leads to the reddish appearance of Martian surface.

8. **The temperature of a planet's surface exposed to the Sun is proportional to the square root of its distance D from the Sun. The semi major axis of Mercury and Saturn are 0.4 and 10 AU respectively. If the day-time temperature and the associated thermal velocity on Mercury at this distance are 500 K and 5 km/s respectively, what are their values on Saturn? What about their values on the day side of Saturn's moon Titan? Although Mercury has a larger mass and smaller radius than Titan, Mercury does not have any significant atmosphere whereas the atmosphere on Titan has comparable pressure and density to those of the Earth atmosphere. Can you suggest why this may be the case?**

   Because Saturn is 25 times further from the Sun than Mercury, the temperature at its distance from the Sun is 5 times lower (as a square root of the distance). The average thermal speed is proportional to the square root of the temperature. Thus, the average thermal speed at Saturn's distance is 2.2 times slower than near Mercury. Because the thermal speed of molecules near its surface is larger than escape speed of Mercury, it has lost all of its atmosphere. In contrast, the thermal speed of molecules is smaller than that of the Titan (despite its slightly smaller mass and larger radius than Mercury), so that Titan has been able to retain its atmosphere.