Astronomy 3 -Solution Set 8

1. **Describe the location of the equinoxes and solstice in the Uranian Sky. What are the seasons like on Uranus?**

   At the summer equinox, the sun will be near the celestial pole of Uranus. As the Uranian year progresses, the sun will circle around the celestial pole and move further and further away, until it approaches the celestial equator in the Uranian Fall. This is the equinox. The sun will soon drop below the horizon for the duration of the winter. When the sun sets, you will be in continuous night for the next decade or two until the planet finally approaches Spring and the sun comes back to the celestial equator.

2. **Given the size of Triton's orbit (R = 355,000 km) and its orbital period (P = 5.877 days), calculate the mass of Neptune.**

   From the formula
   $$P^2 = a^3/GM \tag{1}$$
   we find
   $$M = a^3/GP^2. \tag{2}$$
   Using the above equation with $G = 6.68 \times 10^{-8}$ in cgs unit, we can deduce Neptune's mass to be 10^{29} gm. We can also scale it with that of the Earth using the Moon's period and distance. It turns out to be 17 times that of the Earth.

3. **How can Titan keep an atmosphere when it is smaller than airless Ganymede?**

   Titan orbits around Saturn which is twice as far from the Sun as Ganymede's planet Jupiter. The temperature and thermal speed at the surface of Titan is smaller than that on Ganymede. This difference is sufficient to have the thermal speed exceeds the escape speed on Ganymede so that its atmosphere would be lost. In contrast, the thermal speed is less than the escape speed on Titan so that its atmosphere is retained.

4. **If you piloted a spacecraft to visit Saturn's moons and wanted to land on a geologically old surface, what features would you look for? What features would you avoid?**

   Old surfaces are heavily scarred by craters. Young surfaces are smooth and have little scaring.

5. **A relatively small impact crater 20 km in diameter could be made by a comet 2km in diameter traveling at 30 km/s. Assume that the comet has a total mass of 4.2 billion tones (4.2 $\times 10^{12}$ kg). What is its total kinetic energy? (Hint check chapter 4 of the book). If one megaton of TNT releases 4.2 million billion (4.2 $\times 10^{15}$ joule), how many megaton does the energy released by the comet correspond to? How often do impact of this magnitude occur on the Earth?**

   Kinetic energy of a comet is given by
   $$E = (1/2)Mv^2 = (1/2)\times(4.2\times10^{12}\text{kg})\times(3\times10^4)\text{meter/s})^2 = 1.9\times10^{21}\text{joule} = 0.45\times10^6\text{Megaton}. \tag{3}$$
   Impact of this magnitude occur on the Earth once per million years.

6. **If comets are icy planetesimals left over from the formation of the solar system, why haven't they all vaporized by now?**

   Comets most reside in the outer regions of the solar system well beyond the orbits of the giant planets. At these far reaches of the solar system, the intensity of solar radiation is weak and the equilibrium temperature on the surface of the comets is too low to lead to the vaporization of their constituent material. Comets are scattered into the inner parts of the solar system by distant encounters. Once they enter the inner part of the solar system, they can only survive a few orbits. Thus, most of the comets we see are the relic of icy planetesimals which have not yet been vaporized.

7. **What is the difference between the location where most asteroids are located and that where comets originated from? What is the compositional difference between comets and asteroids?**

Asteroids are mostly located between the orbit of Mars and Jupiter at 2-4 AU. Comets originate from region well beyond the orbit of Neptune (> 25 AU). Asteroids are mostly made of silicates and iron whereas comets are mostly composed of ice.

8. **What evidence do we have that some meteorites have originated inside large bodies?**

A vast majority of meteorites from the asteroid region are composed of chondrules with abundance distribution similar to that of the Sun. They also contain Calcium Aluminum Inclusions (CAI's) which are the decayed daughter nuclei of once radioactive isotopes of Aluminum 26. Radiometric dating suggest that these are the most primitive rocky material in the solar system. However, $\sim 0\%$ of all meteorites are composed purely of iron while some others are mostly composed Silicates. These types of meteorites were once in much larger bodies. The heat released from the fission decay of radioactive isotopes is trapped in the bodies larger than a few km. As their internal temperature rises, the parent bodies of the iron and stone meteorites become molten. The melted iron elements sink to the center of these objects while the lighter density rocky material surface to the top. Subsequent bombardment by other residual planetesimals break up these differentiated parent bodies. The broken pieces from the outer regions of these parent bodies become the stone meteorites whereas those sunk to the central regions emerge as iron meteorites.