**Astronomy 3 -Solution Set 9**

1. **Based on the information given in Figure 12.25, can you estimate the probability of any individual person being killed by a mass extinction event in his/her life time. How does that probability compare withe the probability of a fatal airline accident ?**

   check the book

2. **how are continents built up? describe a few of the processes that have shaped North America.**

   The initial buildup of the continent proceeded through a differentiation process in the earth interior where the molten high-density iron sunk to the core and less dense silicates surfaced to the top. As the planet cools, the molten mantle of the earth continues to undergo convection which pushes around the plates on the surface. In regions above the rising plume, mid ocean ridge form. In regions where continents collide, high mountains and deep trends form. In the plate boundaries, there are also chains of volcanos. Along the coast of California where the North American plate slides pass the Pacific plates, there are long fault lines near which earth quakes occur frequently. In the north end of this boundary, there is a chain of volcanos in Oregon and Washington States.

3. **If life is based on information, what is that information?**

   Living organisms are self-replicating, and the information about how to build a living organism from raw materials is passed down from generation to generation as DNA.

4. **What is the difference between chemical evolution and biological evolution?**

   Chemical evolution is what happens when you mix a bunch of different chemicals together. They may react with one another, but there is no self replication involved. This means that there is no way to "generate complexity," so to speak.

   Biological evolution, on the other hand, *does* involve self replication. This means that a complicated molecule or system of molecules is able to make an exact (or almost exact) copy of itself. If a variant of the system is able to reproduce itself more efficiently, then it's "children" will share the same trait.

   What this means is that as soon as life is able to get a "toe-hold" in the world, biological evolution is able to make life forms increasingly complex almost without limit (eg. human beings). This is impossible with chemical evolution. If you mixed together 180 pounds of carbon, hydrogen, and oxygen, this material would never, ever spontaneously assemble itself into a human being, no matter how long you wait. However, biological evolution is able to produce human beings.

5. **Based on the information given in Figure 9.45, ie South American and African continents started to drift apart 120 million years ago, can you estimate the speed at which they are separating. How does it compare with the crawling speed of a banana slug?**

   The current separation between these two continents are about 3000 miles. If it takes 120 Million years to get to their current relative positions, the speed of their separation would be $\sim$ 3000 miles/120 million years which is $\sim 3cm/s$. A banana slug crawls over 1 meter per minute which corresponds to a speed $\sim 1.6cm/s$. Thus, the spreading of the continents occurs on a comparable speed as the slug goes.

6. **As the Sun gradually brightens in the future, how can the CO2 cycle respond to reduce the warming effect? Which parts of the cycle will be affected? Is this an example of a positive or negative feedback?**

With a small and gradual increase in the brightness of the Sun, the surface temperature of the Earth would increase. This trend may lead to greater evaporation of the Earth ocean. The moist and warm atmosphere may provide more favorable condition for the proliferation of green plants which also enhances the conversion of CO2 to oxygen through the photo synthesis. The elevated water vapor also leads to more frequent rain and more efficient carbon dioxide removal from the atmosphere. The depletion of CO2 in the atmosphere reduces the extent of the green house effect which off-balance the increased solar irradiation. This negative feedback acts as a thermometer which regulates the atmospheric temperature. However, a sudden and large increase in the Sun's luminosity can also lead to a runaway green house effect in which the hot deserts may alter the circulation pattern of the atmosphere and reduce the lush forests. An increase in the industrial usage of air conditioning equipments may increase CO2 emission and strengthen the greenhouse effect. This positive feedback process may quickly transform the earth atmosphere into that comparable to the Venus. In order to avoid this fate, we must be conservative in our energy and environmental policies.

7. **why does the energy produced by fusion in the solar core take so long to reach the solar surface? Describe the processes of radiative diffusion and convection in the solar interior.**

The photons released by fusion is in the gamma ray wavelength range. These photons are quickly scattered by the hot electrons and absorbed by the highly ionized iron nuclei. The excited atoms re-emit photons with lower energy and in random directions which are again absorbed. These re-processing processes occur repeatedly as the photons diffuses heat outwards. The time scale for energy to travel a net distance of the Sun's radius is several million years. The interior of the Sun is divided into two regions. In the radiative region, the heat is transfered primarily through the absorption and re-emission of the photons. In the outer envelope of the Sun, this process is not sufficiently effective that the gas becomes convective. In the convective zone, heat is transported mechanically by the eddies which circulates between the Sun's surface and hot interior.

8. **Use the fact that each cycle of the proton-proton chain converts $4.7 \times 10^{-29}$ kg of mass into energy, along with the fact that the Sun loses a total of about $4.2 \times 10^{9}$ kg of mass each second, calculate the total number of times the proton-proton chain occurs each second in the Sun. Compare quantitatively the amount of mass loss during the entire life of the Sun with its present total mass.**

The number of reaction occurs per second is the total rate of mass loss due to the nuclear reaction divided by the amount of mass converted from mass into energy for each reaction such that it becomes $4.2 \times 10^{9}$kg/s/$4.7 \times 10{-}29$kg $\simeq 0.9 \times 10^{38}$ reactions per second. The total mass of the Sun is $2 \times 10^{33}$ gm. The life span of the Sun is $4.6 \times 10^{9}$ yr $= 1.38 \times 10^{17}$ s. The total conversion of mass during the life span of the Sun is $4.2 \times 10^{9}$gm/s $\times\ 1.38 \times 10^{17}$s $= 5.8 \times 10^{26}$ gm which is $2.9 \times 10{-}7$ the mass of the Sun.

9. **The star 51 Pegasi has about the same mass as out Sun. A planet discovered around it has an orbital period of 4.23 days. The mass of the planet is estimated to be 0.6 times the mass of Jupiter. Use Kepler's third law to find the planet's average distance from the star. What is the orbital speed of this planet? What is the speed of 51 Pegasi's reflex motion?**

According to Kepler's third law,

$$P^2 = a^3/GM_* \tag{1}$$

where $M_*$ is the mass of the star. Since $M_*$ is the same as that of the Sun, it is useful to scale, with the Earth, in the determination of the distance (in terms of an AU) from the planet's period. In this approach,

$$a = \left(\frac{4.23\text{days}}{365.24\text{days}}\right)^{2/3} AU \simeq 0.05\text{AU}. \tag{2}$$

The orbital speed of this planet can also be scaled with the speed of the Earth's orbit which is 30 km/s such that

$$V_p = \left(\frac{1\text{AU}}{a}\right)^{1/2} 30\text{km/s} = 136\text{km/s}. \tag{3}$$

The speed $V_*$ associated with the reflex motion of its host star is the planet's $V_p$ times the mass ratio between the planet ($\sim 0.6M_J$) and its host star (ie the mass of the Sun which is $\sim 10^3 M_J$) such that $V_p(0.6M_J/10^3M_J) \simeq 81.6$m/s.

10. **Based on the Drake equation on p735 of the textbook, estimate the number of communicative civilizations per galaxy from your own estimates of the factors.**

The answer to this depends on how optimistic or pessimistic you are in choosing the fraction of planets that develop life, etc.