**Astronomy 2020 – Space Astronomy & Exploration     Fall 2020**
Homework #6                                                            Due: Nov. 20, 2020

In questions 1-3 below, choose the best answer. Then explain your reasoning in a few complete sentences. Each question is worth 2 pts.

1. Why does Neptune appear blue and Jupiter appear red?
   a. Neptune is hotter, which produces bluer thermal emission.
   b. Methane in Neptune's atmosphere absorbs red light.
   c. Neptune's atmosphere scatters blue light, much as Earth's atmosphere does.
   d. Jupiter has an intense Greenhouse Effect causing it to trap red light.

   b – Neptune's, unlike Jupiter's, atmosphere contains a significant amount of methane. The lack of red light is perceived as blue.

2. Why is Saturn almost as big as Jupiter, despite its smaller mass?
   a. Jupiter's greater mass compresses it more, thus increasing its density.
   b. Saturn's rings make the planet look bigger.
   c. Saturn is further from the Sun, thus cooler, and therefore less compact.
   d. Saturn has a larger proportion of hydrogen and helium than Jupiter, and is therefore less dense.
   e. Jupiter's strong magnetic field constrains its size.

   a – As it turns out, the size and mass of a planet are not always directly related. In fact, Jupiter is near the maximum size of a jovian planet of its composition; any mass added to it would only marginally increase its size and if enough mass was added to it, it would shrink.

3. Did a large terrestrial planet ever form in the region of the asteroid belt?
   a. No, because there was never enough mass there.
   b. No, because Jupiter prevented one from accreting.
   c. Yes, but it was shattered by a giant impact.
   d. Yes, but it migrated to beyond the orbit of Pluto as a result of a gravitational resonance.

   b – Jupiter is a bit of gravitational bully. Jupiter's large mass leads to it having a significant gravitational influence over the asteroid belt. Because of Jupiter's gravitational "tugs", it perturbed the orbits of many of the asteroids, preventing a planet from forming.

4. (3 pts). Of Mercury, Venus, the Moon, and Mars, which world has the greatest erosion? Explain why. In your answer, include the potential sources of erosion and discuss their effect on each planet.

   Of these bodies, Mars has the greatest erosion. While Venus has a thick atmosphere, the winds near the surface are very slow. This means that there is not much erosion. None of the others have a substantial atmosphere, so their wind erosion is negligible. Mars, on the other hand, has global dust storms. These dust storms lead to a significant amount of erosion. There is also evidence on Mars for water erosion in the past, and even some episodic water erosion in current times. There was likely also water erosion on Venus before its runaway greenhouse effect took place. Nowadays it is too hot on Venus for liquid water and so there cannot be water erosion. Erosion on Mercury and the Moon is limited to the effects of the solar wind and micrometeorites.

5. (3 pts). Suppose you could choose any one moon (other than Earth's Moon) to visit in the solar system with a human mission.
   a. Which one would you pick, and why?
   b. What dangers would you face in your visit to this moon?
   c. What kinds of scientific instruments would you want to bring along for your studies?

   Example: You might choose Europa because of its possibility of harboring life, and its large supply of water, which could be used as fuel and also to aid in survival. Dangers would include the temperature (about 100 K = -170 C), lack of an atmosphere, less gravity than the human body is accustomed to (about 13% of Earth's surface gravity), and increased radiation levels. You might want seismometers to determine if there is indeed a subsurface ocean or warm ice mantel. Other useful scientific instruments would study the composition of the ice and search for microbes.

6. (3 pts). Each ring particle in the densest part of Saturn's rings collides with another about every 5 hours. If a ring particle survived for the age of the solar system (4.5 billion years), how many collisions would it undergo?

We simply divide the total time by the time per collision to find the number of collisions:

$$\frac{4.5 \text{ billion years}}{5 \text{ hours}} = \frac{3.94\times10^{13} \text{ hours}}{5 \text{ hours}} = 7.88\times10^{12} = 7.88 \text{ trillion collisions}$$

7. (3 pts). A number of planetary scientists strongly suspect that Europa has a subsurface ocean, even though we cannot see through the surface ice. Explain why scientists think the ocean exists. What is the evidence for such an ocean?

   Water vapor plumes have been tentatively observed erupting on Europa using the Hubble Space Telescope, and that water vapor has to come from somewhere. A subsurface ocean is good solution. There are also surface features which look like icebergs broke apart and refroze. There are few craters, which would suggest regular resurfacing by new ice.

8. (4 pts). A relatively small impact crater 20 kilometers (km) in diameter could be made by an asteroid 2 km in diameter traveling at 30 km/sec (30,000 m/sec).
   a. Assume that the asteroid has a mass of $4\times10^{12}$ kilograms (kg). What is the total kinetic energy of this asteroid? (If you use mass in kg and velocity in m/sec, kinetic energy will have units of joules.)

   Kinetic energy, $K$, is $K = \frac{1}{2}mv^2$. With $m = 4 \times 10^{12}$ kg and $v = 3 \times 10^4 \ \frac{\text{m}}{\text{s}}$, this is $K = \frac{1}{2}(4 \times 10^{12} \text{ kg})\left(3 \times 10^4 \ \frac{\text{m}}{\text{s}}\right)^2 = \mathbf{1.8 \times 10^{21} \ J}$

b. By doing a little web research, convert your answer above to an equivalent in megatons of TNT, the unit used for nuclear bombs. Comment on the degree of devastation the impact of such an asteroid could cause if it struck a populated region on Earth.

Since 1 megaton of TNT is the equivalent of $4.184 \times 10^{15}$ J, this impact would be the equivalent of $\frac{1.8\times10^{21}\text{ J}}{4.184\times10^{15}\text{ J}} = 4.3 \times 10^5 = \mathbf{430,000\ megatons\ of\ TNT}$. The atomic bombs dropped in WWII which led to the destruction of two Japanese cities and hundreds of thousands of lives were the equivalent of only about $\frac{1}{50}$ megatons of TNT. So this impact would be utterly catastrophic for most life currently on Earth.