Chapter 11

27) *Which lists the jovian planets in order of increasing distance from the Sun?*
c) Jupiter, Saturn, Uranus, Neptune. Pluto is not a jovian planet (or a planet at all) and Jupiter is the nearest jovian planet to the Sun.

32) *Why is Io more volcanically active than our moon?*
c)Io has a different internal heating source. In isolated systems radioactive decay heats the interior. In Io tidal forces from Jupiter combined with Io's eccentric orbit causes the interior to be heated. This keeps Io's core molten leading to an increase of volcanic activity in Io, even though it is similar in size to the Moon.

49)*Io loses about a ton (1000 kilograms) of sulfur dioxide per second to Jupiter's magnetosphere.* **a.** *At this rate, what fraction of its mass would Io lose in 4.5 billion years?* **b.** *Suppose sulfur dioxide currently makes up 1% of Io's mass. When will Io run out of this gas at the current loss rate?*
a. Assuming Io loses 1000kg per second (3.2×10^{10} kg per year) for 4.5 billion years, the total mass loss from Io is 1.4×10^{20}kg over 4.5 billion years. Dividing by the current mass of Io (2.933×10^{22}kg from Table E.3), the fraction of mass lost by Io is 1.4×10^{20}kg/8.9×10^{22}kg = 1.6×10^{-3}. Therefore, Io would lose less than 1% of its mass over 4.5 billion years. **b.** Assuming Io out gases rate at a constant, the sulfur dioxide mass ($0.01\times8.9\times10^{22}$kg) divided by the gas loss rate (3.2×10^{10} kg per year) gives a total out gassing time of 28.2 Gyr. The lifetime of the Sun is approximately $\sim$ 9 Gyr, so Io will not stop out gassing before the end of the solar system.

Chapter 12

25) *The asteroid belt lies between the orbits of*
b) Mars and Jupiter. Orbital resonances, primarily from Jupiter, create stable and unstable regimes for asteroid orbits between Mars and Jupiter.

30) *How big an object causes a typical shooting star?*
a) a grain of sand or pebble. Fortunately, meteors are generally small remains of the early solar system.

45) *It's estimated that there are a million asteroids 1 kilometer across or larger. If a million asteroids 1 kilometer across combined into one object, how big would it be? How many 1-kilometer asteroids would it take to make an object as large as the Earth? (Hint: You can assume they're spherical. The expression for the volume of a sphere is* $\frac{4}{3}\pi r^3$*, where r is the radius.)*
Assuming the asteroids could be packed together, the volume of the combined asteroids is the number of asteroids multiplied by the volume each asteroid occupies ($\frac{4}{3}\pi(1/2\text{km})^3$). The combined asteroid has a volume of 5.3×10^5 km^3. Dividing the volume of Earth by the volume of a kilometer sized asteroid, 2.06×10^{12} kilometer sized asteroids are necessary to create an object as large as Earth.

46) *A relatively small impact crater 20 kilometers in diameter could be made by a comet 2 kilometers in diameter traveling at 30 kilometers per second (30,000 m/s).* **a.** *Assume that comet has a total mass of* 4.2×10^{12} *kilograms. What is its total kinetic energy? (Hint: The kinetic energy is equal to* $\frac{1}{2}mv^2$*, where m is the comet's mass and v is its speed. If you use mass in kilograms and velocity in m/s, the answer for kinetic energy will have units of joules.)* **b.** *Covert your answer from part a into an equivalent in megatons of TNT, the unit used for nuclear bombs. Comment on the degree of devastation the impact of such a*

comet causes if it struck a populated region on Earth. (Hint: One megaton of TNT releases 4.2×10^{15} joules of energy) **a.** The total kinetic energy is $0.5\times4.2\times10^{12}kg\times$(30,000 m/s)^2 or 1.9×10^{21} joules. **b.** To convert to megatons of TNT divide the total kinetic energy of the comet(1.9×10^{21} joules) by the number of joules in one megaton of TNT (4.2×10^{15} joules per megaton of TNT). This gives 4.5×10^5 megatons of TNT, which is about 10^5 times larger than the largest nuclear bomb ever detonated (the Tsar Bomb with an energy of $\sim$ 50 megatons of TNT). The comet would utterly destroy any city it impacted.