ASTR 321-Fall 2009
Problem set #5

due Tuesday nov 10

1) Every time Neptune scatters bodies to Jupiter, Neptune gains energy and its orbit becomes larger. How much mass would Neptune have to scatter to Jupiter for Neptune's orbit to have changed from a circular orbit at 22AU to a circular orbit at 30AU? Give the answer in terms of Neptune's mass and assume that all scattered objects approached Neptune on circular orbits but left on orbits with aphelia of 26AU (average between 22 and 30) and perihelia of 5 AU.

2) After the solar nebula had lost its gas, there were situations where large bodies could lose energy relative to smaller ones by a process called "dynamical friction". After many interactions the big bodies tend to have lower relative speeds than the smaller ones. Because relative speeds are determined by inclinations and eccentricities, the orbits of the larger bodies settle towards the nebula midplane and also become more circular. The difference in speeds between low mass and high mass bodies is analogous to the velocity of gas molecules of gas where equipartition of kinetic energy cases massive molecules to move slowly than less massive ones. All bodies, regardless of mass tend to have the same kinetic energy. The large solid objects in the nebula would have smaller relative speeds but they have the same kinetic energy (*neglect orbital speed here – the speed is the relative speed between particles due to differences in inclination and eccentricity*) as small objects.

Assume that the thickness of the disk in problem 2 was typical for the distribution of 1 km diameter bodies in the solar nebula at 3AU. Estimate the thickness of the disk at this location for 1000 km bodies.

3) What diameter 5 km/s rock does it take to explode a 1 km asteroid that is held together only by its self gravity? To blow it up, the projectile has to have a kinetic energy > $\frac{3}{5}\frac{GM^2}{r}$?

What size "rock" does it take to blow up Earth assuming that only self gravity is important. (hint; For Earth, use the actual impact speed that takes into account the escape speed and is higher than 5 km/s.)

4)An igneous rock from a solar system body is returned to Earth that contains four different minerals with the following isotopic compositions: see backside

Mineral	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Aite	18.0	.945
Bite	10.0	.840
Cite	6.00	.785
Dite	2.00	.738

^{86}Sr and ^{87}Sr are stable isotopes but ^{87}Rb is radioactive and decays to ^{87}Sr with a decay constant (time to decay by e^{-1}) of 7 x 10^{10} years. When the minerals formed by crystallization from a liquid they had identical $^{87}Sr/^{86}Sr$ ratios.

Plot the data on a graph of $^{87}Sr/^{86}Sr$ (y axis) versus $^{87}Rb/^{86}Sr$ (x axis) and compute the age of the rock. What was the initial Sr isotopic composition when the rock solidified?