Astro 102/104 Our Solar System **Spring 2008**

NAME:______________________ Section Number:______________

Homework 11: Satellites, Rings, and the Trans-Neptunian Region

Due: in your section on **the week of April 21th**. Be neat and concise, show your work, and remember units. An answer without the correct units is wrong.

Suggested reading: Lecture notes 30, 31, and 32, and chapters 11.2, 11.3, and 12.3.

1. Planetary ring systems:

   a. [1 Point] Which jovian planets have rings?

      All of them!

   b. [3 Points] Why do these planets have rings? Explain the current theory, and mention two early theories that were later discarded (and give one reason why each was discarded).

      Current theory: new particles must be continually supplied to the rings. The most likely source is numerous small moons that formed in the disks of material orbiting the young jovian planets.

      Early theory: a large moon came too close to the planet and was ripped apart by tidal forces. This theory was discarded because moons tend not to wander away from their orbits, and only a close encounter with an asteroid or comet can deflect a large moon, which is unlikely to have happened with all jovian planets.

      Early theory: ring particles are leftover chunks of ice and rock from when the jovian planets were forming. This theory was discarded because such particles could not have survived for billions of years due to the effects of micrometeorite impacts and other processes.

      A full discussion can be found in your textbook, starting on p. 352

   c. [2 Points] How does the rotation of a ring system differ from the rotation of a solid disk (such as a DVD)? [Hint: write down how velocity varies with radius for the solid disk, and compare this to Kepler's 3rd Law for ring particles]

      For a solid disk, $v = 2\pi r/P$, where the period P is constant across the disk.
      For particles, $P^2 = a^3$, which can be rewritten as $(2\pi a/v)^2 = a^3$ or $v = 2\pi/a^{1/2}$.
      *Because **r** and **a** are both measure of distance from the center of the orbit, we can see that while velocity **increases** with distance for a solid disk, it **decreases** with distance for the ring particles.*

2. News from Enceladus [Hint: for these questions, you'll need to do a little research into Cassini's recent observations of Enceladus – a good place to start is with the press releases on the Cassini website: www.saturn.jpl.nasa.gov]

   a. [3 Points] What is the difference between an *eclipse*, a *transit*, and an *occultation*?

      *An **eclipse** is when one object moves into the shadow of another. Occultations and transits are different types of eclipses.*

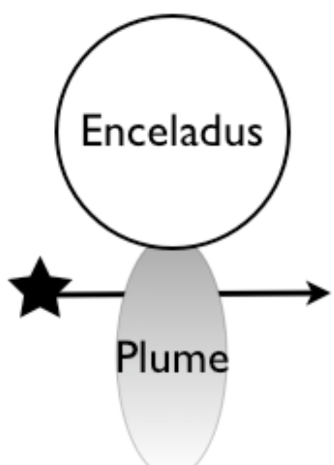
      *An **occultation** is when the nearer object appears larger and completely hides the object further away.*

      *A **transit** is when the nearer object appears smaller in size than the more distant one.*

   b. [2 Points] Why was the Cassini spacecraft's discovery of Enceladus' water plume in 2005 so surprising? [Hint: given the moon's size and location, would you have expected it to be geologically active?]

      *Because Enceladus is so small (about 300km in diameter), it should not have an internal heat source from differentiation, contraction, accretion, or radioactivity. Because it has a small orbital eccentricity (e ~ 0.0047), astronomers did not expect Enceladus to be heated by tides from Saturn. Prior to the Cassini discovery, Enceladus was thought be an geolocially inactive iceball – with its active water vapor plumes, however, Enceladus is telling us that **something** is heating its interior.*

   c. [2 Points] On October 24, 2007, the Cassini Spacecraft observed an occultation of the star zeta Orionis by Enceladus' plume. Draw a picture of how zeta Orionis, Enceladus, and Enceladus' plume were oriented for this observation, and explain what was discovered about the density of the plume.



By observing how the brightness of zeta Orionis changed as it passed behind Enceladus' plume, astronomers learned that the plume has four dense regions, and thus must originate from four individual jet sources.

d. [2 Points] On March 12, 2008 (just a few weeks ago!), Cassini made a close flyby past Enceladus, and the spacecraft went through part of Enceladus' plume. What did we learn from this flyby about the plume's chemistry?

The Cassini spacecraft, with its Ion and Neutral Mass Spectrometer instrument, observed that the interior of Enceladus has a composition similar to that of a comet. The densities of volatile gases, water vapor, carbon dioxide, carbon monoxide, and organic materials were roughly 20 times denser than expected.

3. [2 Points] Pluto's orbit crosses that of Neptune – is Pluto at risk of colliding with Neptune? Why or why not?

Pluto is ***not*** *at risk of colliding with Neptune because the two bodies are in a 2:3 orbital resonance (which means that for every two orbits Pluto makes around the Sun, Neptune will complete two orbits). In this configuration, Pluto and Neptune never get closer than 17AU to each other - when the two "line up" every two Pluto orbits and three Neptune orbits, fortunately for Pluto they're nowhere near each other! And when Pluto "crosses" Neptune's orbital path, Neptune will have already moved to a different part of its orbit.*

4. Io is HOT!

a. [1 Point] Scientists have never measured Io's internal temperature. What evidence do we have of Io's strong internal heating?

Io has extensive volcanism occurring on its surface today, and therefore must have an internal heat source.

Also, while we haven't measured Io's internal temperature, we ***have*** *measured the surface temperature, and Io's heat flux is large enough to detect with thermal infrared wavelengths. The surface temperature exceeds the equilibrium temperature, which is evidence for internal heat.*

Finally, there are theoretical calculations for Io's tides that show that Io ***should*** *have strong internal heating.*

b. [2 Points] Explain how the resonance among Io, Europa, and Ganymede leads to Io's tidal heating.

Ganymede, Europa and Io are in a 1:2:4 orbital resonance, meaning that for every one orbit of Ganymede, Europa orbits twice, and Io orbits 4 times. This resonance returns the three moons to the same position (Europa and Ganymede lined up on one side of Jupiter, with Io on the other side) every 7 days, and their three orbits are kept slightly elliptical from the recurring gravitational tugs. Because of Io's elliptical orbit, the strength of the tidal force from Jupiter changes over the course of one orbit, and the flexing in Io's interior causes its heating. See p. 353 in your textbook for an orbital diagram.