Homework 10: Saturn, Uranus and Neptune

Due: in your section on the week of April 14th. Be neat and concise, show your work, and remember units. An answer without the correct units is wrong.

Suggested reading: Lecture notes 27, 28, and 29, and chapters 10.2, 7.1, and 11.1.

1. [3 Points] Suppose the material that formed Jupiter came together without any rotation so no “jovian nebula” formed and the planet today wasn’t spinning. How else would the Jovian system be different? List at least THREE effects and explain each in a sentence.

   These moons were not "captured"

   There would be no belts or zones in the atmosphere
   There would be no magnetic field
   Jupiter would not be oblate, it would be perfectly spherical
   There would be no moons, since there is no nebula from which they could form
   There would be no rings, because there would be no moonlets that could be tidally disrupted and torn apart to form rings.

2. [2 Points] If Saturn’s rings are not solid, why do they look solid when viewed through a small telescope?

   Saturn’s rings look solid because the angular sizes of the objects that make up the rings are smaller than the resolution of the telescope.

3. [2 Points] Describe the seasons on Uranus. Why are the Uranian season different from those on any other planet?

   The seasons on Uranus are very extreme. Winter plunges half of the planet in complete darkness. In summer the opposite occurs with the entire hemisphere being illuminated by the sun. Only in the Spring and Fall is there a rising and setting of the Sun. Because Uranus has an 88 year orbit, the hemisphere experiencing winter, is in dark for several decades.

   These extreme seasons come from Uranus’s 98 degree axis tilt. Uranus is essentially laying on its side!
4. [3 Points] Explain why the atmosphere of Neptune has features that are like Jupiter and Saturn while the atmosphere of Uranus is essentially featureless.

Scientists are not entirely sure. This fact may be attributed to Uranus having less internal heat than the other jovian planets. Uranus's extreme seasons, due to its axis tilt, may also play a part as recent observations show some storms as sunlight returns to the northern hemisphere.

5. Detecting Neptune:

a. [2 Points] At what planetary configuration is the gravitational force of Neptune on Uranus at a maximum (Draw a picture or describe in words)?

b. [4 Points] For this configuration, calculate the gravitational force exerted by the sun on Uranus and by Neptune on Uranus.

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F_s = \frac{G M_s M_u}{d^2}, \quad F_N = \frac{G M_N M_u}{d^2}
\]

The gravitational force is at a maximum when the Sun, Uranus, and Neptune are aligned in a straight line.

\[
F_s = \frac{G M_s M_u}{(3 \times 10^8 \text{m})^2} = \frac{6.67 \times 10^{-11} \text{ m}^3}{\text{kg}^2} \times \frac{(1.99 \times 10^{30} \text{ kg}) (8.68 \times 10^{25} \text{ kg})}{(3 \times 10^{12} \text{ m})^2} = 1.25 \times 10^{21} \text{ N}
\]

\[
F_N = \frac{G M_N M_u}{(1.5 \times 10^{12} \text{ m})^2} = \frac{1.67 \times 10^{-11} \text{ m}^3}{\text{kg}^2} \times \frac{(8.68 \times 10^{25} \text{ kg}) (1.02 \times 10^{26} \text{ kg})}{(1.5 \times 10^{12} \text{ m})^2} = 2.57 \times 10^{17} \text{ N}
\]

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\text{Distance between Neptune and Uranus: } D_N - D_u = 304u - 204u = 1.5 \times 10^{12} \text{ m}
\]

\[
\text{Fraction} = \frac{F_N}{F_s} = 2 \times 10^{-4} = 0.02\%
\]

c. [2 Points] By what fraction is the sunward gravitational pull on Uranus reduced by the pull from Neptune?

d. [2 Points] Based on your calculations, do you expect that Neptune has a relatively large or relatively small effect on Uranus’s orbit?

Based on the fact the Neptune reduces the sunward pull by 0.02%, Neptune has a relatively small effect on Uranus's orbit. Considering that Neptune was discovered by detecting this small effect on Uranus, it makes Neptune’s method of discovery all the more amazing.