PHY 241 Planetary Systems - Coursework #4

Due: Tuesday, November 2, 2010 4pm

References:
Look in your introductory physics text for a few expressions for angular momentum, moment of inertia, and other basic concepts and relations.

Some useful numbers

Object	Mass (kg)	Radius (km)	Rotation Period	Semi-major axis	Eccentricity
Sun	1.98×10^{30}	6.96×10^{5}	~ 25 days		
Earth	5.97×10^{24}	6,378	23.93 h	1.00 AU	0.0167
Moon	7.35×10^{22}	1,737	synchronous	384,400 km	0.0549
Mars	6.41×10^{23}	3,394	24.64 h	1.523 AU	0.0934
Phobos	1.08×10^{16}	11.2	synchronous	9380 km	0.0151
Jupiter	1.90×10^{27}	71,398	9.92 h	5.203 AU	0.0483
Io	8.93×10^{22}	1821	synchronous	421600 km	0.0041
Saturn	5.68×10^{26}	60,330	10.66 h	9.537 AU	0.0541
Mimas	3.85×10^{19}	199	synchronous	185,520 km	0.0202

Additional values needed can be found on the web (wikipedia is a good source).

1. Roche Radius [2 marks]

   a) Assuming a reasonable density for a human being, compute the roche radius for a human orbiting the Earth. List your answer in metres and Earth radii.

   b) Why aren't astronauts aboard spacecraft (e.g. the Space Shuttle) tidally disrupted when they orbit just above the Earth's surface (e.g. at $r = 1.1R_{\oplus}$)?

2. Height of Equilibrium Tides [5 marks]

   a) Explain how forces from an external mass can tidal deform a planet or satellite.

   b) Compute the height of the equilibrium tide raised in the satellite Io by Jupiter. List your answer in metres.

   c) The actual height of the tide raised in Io by Jupiter is about 150 metres. Comment on any discrepancy between the two numbers. What physical property of the satellite might cause them to differ?

   d) Describe how the eccentric orbit of Io affects the height of the tide raised in Io by Jupiter? What consequences does this have for Io and its orbit?

3. The evolution of the Sun-Earth system (neglecting the Moon). [11 marks]

   a) Draw a diagram of a top down view of the Sun-Earth system which shows the following:
      i. The direction of Earth's rotation.
      ii. The tidal bulges that the Sun raises in Earth.
      iii. The force exerted by the Sun on each tidal bulge on the Earth.

   b) In a few sentences and using the diagram you've constructed above, explain how the forces exerted by the Sun on the Earth, exerts a net torque.
      i. How does this torque affect Earth's rotation frequency?
      ii. What will the final rotation frequency of the Earth be?

iii. Assuming the Earth is a uniform sphere, compute the change of the Earth's angular momentum due to solar tides. Where does this angular momentum go?

c) Assuming the total angular momentum of the Sun-Earth system is conserved,

i. Describe how this torque affects Earth's orbit about the Sun?

ii. Using appropriate conservation laws and equations quantify any changes in Earth's orbit (e.g. compute changes in semi-major axis, its okay to assume a circular orbit)