Tentamen för Rymdfysik I/MN1/NV1
2003-04-24

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Please write your **name** on **all** papers, and on the first page your **address, e-mail**, and **phone number** as well.
Time: 8:00 - 13:00
Allowed tools: Mathematics Handbook, Physics Handbook, enclosed formula sheet.

1. The answers to the following qualitative questions should be a few lines for each of the 1-p questions, perhaps ten lines and a figure for the 2-p problems.
   (a) What is the solar wind? (1 p)
   (b) Does the solar wind hit the Earth's ionosphere? Why/why not? (1 p)
   (c) What do we mean by a frozen-in magnetic field? When is this concept appliccable? (1 p)
   (d) When launching a rocket, why is it theoretically best do burn the fuel as fast as possible? (1 p)
   (e) Explain the concept ”loss cone”. (2 p)
   (f) Why are structures in a magnetized plasma often much larger along the magnetic field lines than across them? (2 p)
   (g) What are the radiation belts? Why do they exist? Where are they (draw a picture)? (2 p)

2. When passing the subsolar point, which is the point where the magnetopause is intersected by the Sun-Earth line, a spacecraft records a magnetic field as in Figure 1.
   (a) Estimate the current density (A/m^2) in the magnetopause current.
   (b) Also do a rough estimate for the total dayside magnetopause current in ampères (correct to within a factor of 100 or so), using some reasonable assumptions on magnetospheric size.
   (c) Estimate the stand-off distance, i.e. the distance of the magnetopause from the center of the Earth.
   (d) Estimate the solar wind number density (m^{-3}), if the solar wind speed was 200 km/s.

   One may assume that the geomagnetic field is described by a dipole field all the way out to the magnetopause, that the interplanetary field as well as thermal pressure may be neglected, and that one out of four ions in the solar wind is a He$^+$ while all the rest are protons. (5 p)

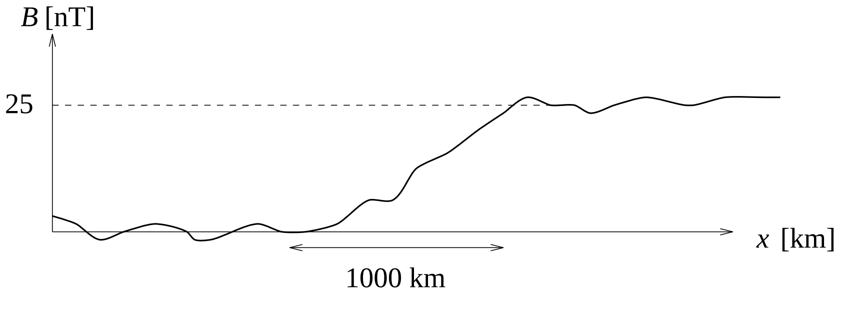

Figure 1: The x-axis points away from the sun.

3. The Rosetta spacecraft should have been launched three months ago, but due to problems with the Ariane V launch vehicle it still stands on the ground. Rosetta's destination was the comet Wirtanen, which should have been reached after more than eight years in space, during which time Rosetta would have flown by Mars in summer 2005, Earth in autumn 2005, and Earth again two years later. We are now replanning the Rosetta missions for a launch in February 2004 aiming for another comet, known as Churyomov-Gerasimenko, via another series of planetary flybys: Earth-Mars-Earth-Earth. Before deciding for this mission, we discussed some other alternatives, including the possibility to go close to Venus. It was not obvious that this could be done, as Rosetta was not designed to come closer to the sun than 1 AU.

   (a) What is the benefit of complicated trajectories with several planetary flybys, like the Rosetta trajectores for Wirtanen and Churyomov-Gerasimenko? What is the physics behind this? Why do you think we were looking at the possibility of flying by Venus? (2 p)

   (b) In Uppsala, we have built two Langmuir probes for Rosetta, to measure the density, the temperature and the flow speed in the plasma around the comet. The probes are spherical with a radius of 25 mm. They are made of titanium with a surface coating of titanium nitride, which has absorption coefficient $\alpha = 0.47$ and emission coefficient $\epsilon = 0.10$. There is no power dissipation within the spheres. Neglecting any heat exchange with other structures on the spacecraft, what would the equilibrium temperature of the spherical probes be at Earth orbit (1 AU) and at Venus orbit (0.72 AU)? (3 p)

4. (a) Show that the kinetic energy of a charged particle moving in a magnetic field, which is constant in time but may vary arbitrarily in space, is constant. (2 p)

   (b) Consider an electron with a kinetic energy of 1 keV and pitch angle 90° moving in the equatorial plane at a distance of 4 R_E from the center of the Earth. How long time does it take for this electron to drift one complete orbit around the Earth? The geomagnetic field may be taken to be a dipole field with strength 30 μT at the ground at the equator. (3 p)

5. (a) Derive (from the equation of motion of a neutral gas and an assumption of constant gravitational field) an expression showing why the concentrations of neutral molecules decrease approximately exponentially with increasing altitude, and why the concentration of atomic oxygen (O) decreases slower with altitude than the N_2 density, which in turn decreases slower than the concentration of molecular oxygen (O_2). State explicitly all assumptions you make. (2 p)

   (b) A typical electron density profile for the Earth's ionosphere, i.e. the electron number density n as a function of height h above ground, typically has $n(0) = n(\infty) = 0$ and a maximum at an altitude h of a few hudred kilometers. What are the physical reasons for why the ionosphere looks like this? (2 p)

   (c) Name two planets or moons in the solar system, one which has an ionosphere and one which does not, and tell briefly (one line of text or so) why they have/do not have ionospheres. (1 p)