Problems, Tutorial 4

Space physics EF2240, 2015

1.

a) Figure 1a shows Voyager 2 measurements of the electron density of the Jupiter dayside ionosphere as a function of altitude above the surface. The surface of Jupiter is defined as the region where the pressure of the neutral gas is 1 bar = 100 kPa. It is still not known if the main ionospheric layer with the peak at around 1900 km altitude is associated with ionization of atomic hydrogen or molecular hydrogen. Supported by a calculation, state which alternative you believe is correct.

In Table 1b are given values of ionization cross sections $\bar{\sigma}$ (the same as the absorption coefficient called a_a in Fälthammar), for various wavelength intervals of the incoming solar EUV radiation. Use the values in the range 504-804 Å. Assume that the layer can be described by a Chapman profile, and that the neutral atmosphere is exclusively made up of either molecular or atomic hydrogen. Assume (somewhat unrealistically) that the temperature in the Jupiter atmosphere is constant with altitude and has a value of 300 K. The gravitational acceleration at the Jupiter surface is 23.1 ms^{-2}.

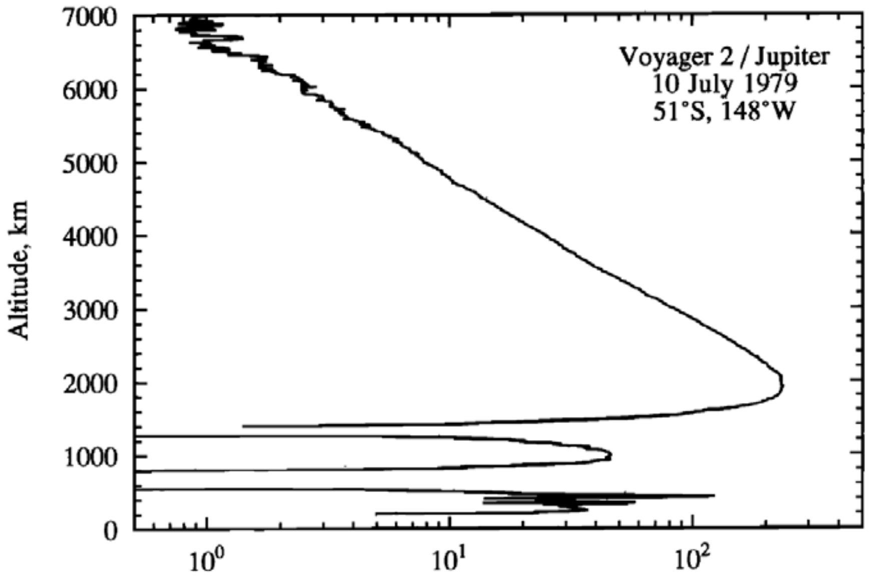

Figure 1a

Electron number density in Jupiter's ionosphere derived from Voyager 2 radio measurements at occultation exit. Altitude reference is the 1-bar equipotential surface defined by ***Lindal et al.*** [1981]. *(Hinson et al., 1998)*

MEAN CROSS SECTIONS AND FLUXES

$\bar{\sigma}(H_2)$	($\lambda < 504$)	1.7×10^{-18} cm^2
$\bar{\sigma}(H_2)$	($804 > \lambda > 504$)	6.1×10^{-18} cm^2
$\bar{\sigma}(He)$	($\lambda < 504$)	3.3×10^{-18} cm^2
$\bar{\sigma}(H)$	($912 > \lambda > 804$)	5.0×10^{-18} cm^2
$\bar{\sigma}(H)$	($804 > \lambda > 504$)	3.0×10^{-18} cm^2
$\bar{\sigma}(H)$	($\lambda < 504$)	6.0×10^{-19} cm^2
$\bar{\mathfrak{F}}_\infty$	($\lambda < 504$)	6.7×10^{8} ph/cm^2/sec[a]
$\bar{\mathfrak{F}}_\infty$	($804 > \lambda > 504$)	4.0×10^{8} ph/cm^2/sec[a]

Table 1b (Gross and Rasool, 1964)

b) Assuming that the main peak electron density maximum is representative for the whole dayside, estimate the minimum nightside electron density at 1900 km altitude, assuming that the ionosphere is corotating with Jupiter. Calculate the result for both assumptions; the layer consisting of either atomic and molecular hydrogen. The recombination coefficients for these two cases are given in Table 2c (entries 9 and 13), in units of cm^{3}s^{-1}. What can you say about the nightside electron density compared to the dayside one?

Recombination	(9)	$H_2^+ + e \rightarrow H' + H''$	$\alpha_9 = 10^{-8}$
	(10)	$HeH^+ + e \rightarrow He + H$	$\alpha_{10} = 10^{-8}$
	(11)	$He^+ + e \rightarrow He$	$\alpha_{11} = 10^{-12}$
	(12)	$H_3^+ + e \rightarrow H_2 + H$	$\alpha_{12} = 10^{-8}$
	(13)	$H^+ + e \rightarrow H$	$\alpha_{13} = 10^{-12}$
	(14)	$H + H + X \rightarrow H_2 + X$	$\alpha_{14} = 10^{-32}$
	(15)	$H + e \rightarrow H^- + h\nu$	$\alpha_{15} = 10^{-16}$

Table 2c (Gross and Rasool, 1964)

(From Exam, Oct., 2009.)

2. Consider the following model of the magnetic field in the central part of the geomagnetic tail:

$$\mathbf{B} = \begin{cases} -B_0\hat{\mathbf{x}} & , \quad y < -a \\ B_0\hat{\mathbf{x}}\dfrac{3a^2y - y^3}{2a^3} & , \quad -a \le y \le a \\ B_0\hat{\mathbf{x}} & , \quad y > a \end{cases}$$

where B_0 = 10 nT, a = 2000 km and the coordinates are defined as in Figure 1.

a) Calculate the current density $j(x,y)$ (magnitudes and directions as functions of position). Also calculate the numerical value at $y = 0$.

b) Calculate the total current floating in an 80 R_E long magnetotail.

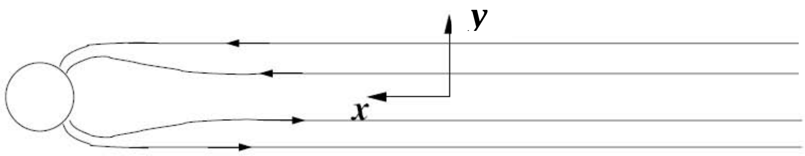

Figure 2

3. Let the geomagnetic field be approximated by a dipole field. Assume that the magnetospheric plasma in the equatorial plane at 5 R_E is made up of protons with an energy of 1 eV and electrons with energy 10 keV. Both particle populations have a pitch angle of close to 90°, which means that they will not move far from the equatorial plane before they mirror. Calculate the grad-*B* drift for both particle populations, the direction of the drift, and the time it takes them to drift around Earth once.

4. Estimate the voltage drop over the magnetosphere (in the east-west) direction, when the solar wind velocity is 350 km/s, and IMF Bz = -7 nT.

5. En electron is situated right above the magnetic pole at an altitude of 10 000 km and is moving down towards Earth with a pitch angle of 15°. At what altitude will the electron mirror and start moving upwards?

6. A satellite has made a number of measurements of the electric field **E** and the magnetic field **B** at 700 km altitude, where you can neglect collisions in the ionospheric plasma. The measurements have been made in the northern hemisphere, and the magnetic field thus points into the plane of the paper in the figure below. This figure is a polar diagram, with the magnetic pole in the centre of the plot. The distance from the centre represents (magnetic) latitude. Instead of longitude, the local time is used, where 12 represents the direction of the sun. For

each measurement point the **E**-field is shown by a vector.

Draw the direction of the plasma drift (perpendicular to **B**) for each measurement point. For the point where the values of the fields are given, also calculate the magnitude of the drift velocity. You can assume that **B** is everywhere directed perpendicular to the plane of the paper.