Problems, Tutorial 2

Space physics EF2240, 2014

The answers to some of the exercises may vary considerably, depending on what approximations and assumptions one has used. This may not necessarily mean that the answer is "wrong", in particular when dealing with estimates of orders of magnitude. If in doubt, do not hesitate to ask at a lecture or tutorial, or via email. Some exercises may seem trivial, but are there to let the student get a feeling for typical magnitudes and dimensions.

1. If the solar wind has the constant velocity 400 km/s, how long does it take for a structure in the solar wind to travel from the sun to the Earth, and to Jupiter, respectively.

2. At Earth orbit the angle ψ between the solar wind magnetic field in the ecliptic plane and the sun-earth line is approximately $45°$ when the solar wind has its average velocity of 320 km/s. On the day of May 11, 1999 (known as "the day the solar wind disappeared") the solar wind velocity decreased to very low values, down to 150 km/s. (The solar wind density was also very low.) Calculate the angle ψ for this solar wind velocity.

3. Based on the density and speed of the solar wind measured near Earth, estimate the mass loss from the sun due to the solar wind. Express your estimate in terms of kg $s^{-1}$and in $M_{\odot}$ yr^{-1} (solar masses/year).

4. In the ionospheric E-region, the change in electron density n_e is given by

   $$\frac{dn_e}{dt} = q - \alpha n_e^2$$

   where q is a term describing the production of new plasma due to ionization by energetic sunlight, and the second term describes recombination. For the E-region you can take $\alpha = 5 \cdot 10^{-7}$ cm^3s^{-1}. When the ionosphere (the lower parts of which are tied to the Earth by friction and co-rotate with it) enters the night-side, the ionization due to sunlight is suddenly turned off, and we can set $q = 0$.

   a) Calculate how long it takes for the electron density to decrease from its dayside value ($\approx 10^5$ cm^{-3}) to $2 \cdot 10^3$ cm^{-3} (which is a typical value of the electron density in the nightside E-region.)

b) In the upper parts of the ionosphere the temporal variations of the electron density can be modelled by the equation

$$\frac{\partial n_e}{\partial t} = q - \beta n_e$$

where the second term describes losses due recombination of atomic ions. This differs from lower altitudes where molecular ions dominate. Note that here the recombination is proportional to n_e not the n_e^2. β is called the attachment coefficient. Figure 4 shows the maximum plasma frequency (associated with the F2 layer) for a few days in December, 1990, and 1994. (N.B.: it is not the angular frequency that is shown, but ordinary frequency.)

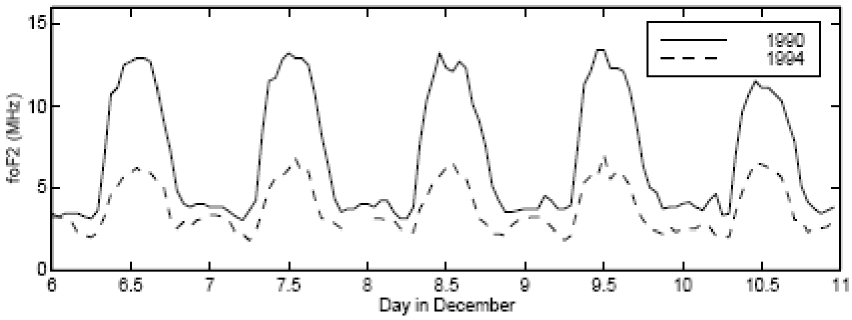

Figure 4

Assuming that that the rapid decrease from the maximum plasma density is due to recombination after an abrupt entrance into the night side, make a rough estimate of the value of the attachment coefficient β in the F2 layer in December 1990.

5. Derive an expression for the altitude at which a Chapman layer has its maximum density.

6. Figure 6 shows the electron density (solid curve) as a function of altitude of the Venus ionosphere, measured by the Mariner 10 spacecraft [from Bauer and Hartle, 1974]. Assume (unrealistically) that the atmosphere has a constant temperature of 400 K. Assuming also that the atmospheric absorption coefficient is 10^{-24} m^2, that the atmosphere consists only of CO_2 and that the ionospheric electron density maximum corresponds to a Chapman layer, determine

   a) the scale height of the Venus atmosphere.

   b) the neutral atmosphere particle density at the Venus surface.

   (Hints: the atomic weights of Carbon and Oxygen are 12 amu and 16 amu, respectively. The gravitational acceleration at the Venus surface is 8.87 ms^{-2}.)

   (From Exam, October 2008)

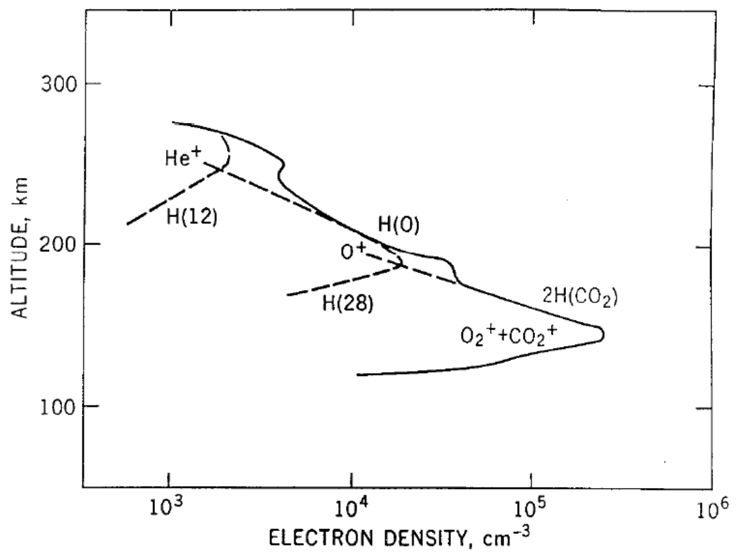
300
200
100
ALTITUDE, km
He+
H(12)
H(0)
O+
H(28)
2H(CO2)
O2++CO2+
10^3
10^4
10^5
10^6
ELECTRON DENSITY, cm^-3

Figure 6