Problems, Tutorial 5

Space physics EF2240, 2014

1. The interplanetary current sheet (sometimes called the neutral current sheet) is the region close to the ecliptic plane where the polarity of the interplanetary magnetic field changes sign (see Figure 1). Assume that between distances of 1 and 2 A.U. (astronomical units) from the sun, the magnetic field is parallel to this sheet (apart from some small-scale variations), and has the same constant absolute value on both sides of the current sheet. If this value is 5 nT, how much current floats in the interplanetary current sheet between 1 and 2 A.U.? (*From Exam Oct. 2008.*)

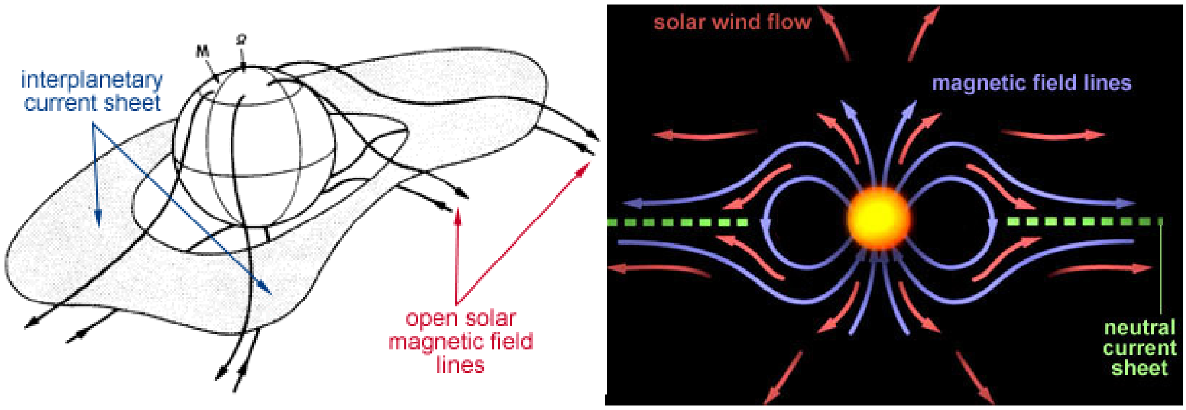
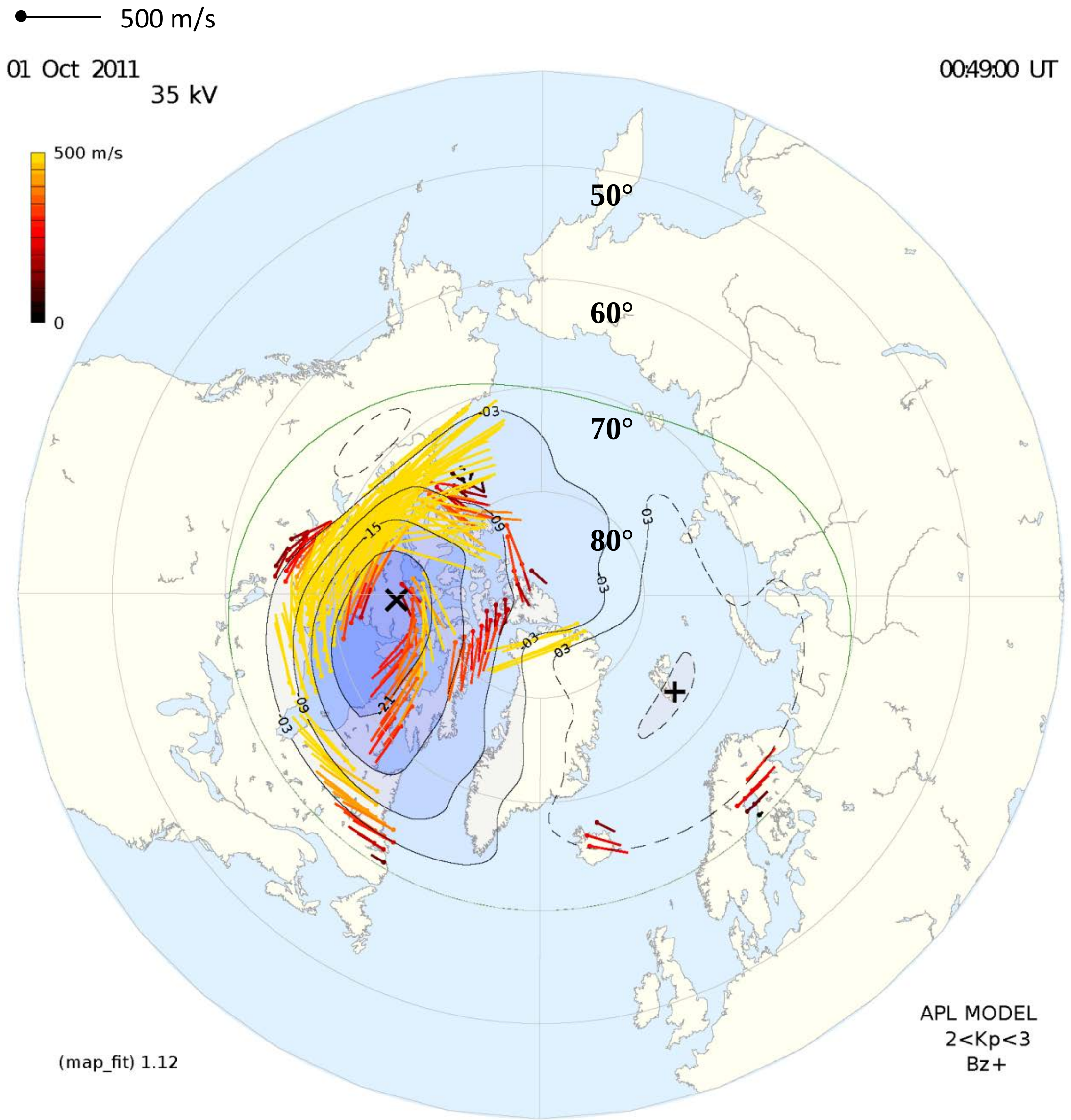


Figure 1

2. The figure below shows recent radar measurements of ionospheric **E**×**B** plasma drift velocities. For each measurement point (indicated by a dot) the direction and size of the velocity is indicated by a vector starting from that point. The scale is given by a vector at the top left. The geomagnetic latitude is indicated by the grey rings.



a) These measurements are taken from the F-region, at an altitude of 300 km. Using a velocity measurement from the figure, calculate the ionospheric electric field strength at this altitude over Iceland (where it is night at the time of the plot) for one of the points in the plot.

b) Assuming that the electric field is the same in the E-region, estimate the current densities of the Pedersen and Hall currents driven by the electric field of from Exercise 1a). Sketch a figure of the directions of the electric field, and the current. *(From Exam Oct. 2011.)*

3. For a cosmic ray to be able to penetrate directly into the Earth's atmosphere close to the equator, it has to have a gyro radius at least as great as the size of the magnetosphere itself, otherwise it will begin to gyrate around a field line, and move towards the poles.

a) Estimate the energy of a cosmic ray particle for this to happen, if the particle is a proton. What about an alpha particle? For the evaluation of the gyro radius use the strongest magnetic field the particle will encounter in the equatorial plane.

b) How strong a field would you need to use if you wanted to artificially shield a spacecraft from particles of energies less than 10^8 eV? Assume that the magnetic field is constant within a distance of 100 meters of the spacecraft.

4. Figure 4 shows the Cocoon nebula, which is an approximately spherical emission nebula associated with an HII region, surrounding a single central star. It has a diameter of about 15 light years. Assuming that the HII region contains only (ionized) hydrogen and using the fact that the recombination coefficient of hydrogen, α_H, varies with the electron temperature T_e as below, determine the electron temperature in the nebula.

The expression for the recombination coefficient is

$$\alpha_H(T_e) = 2 \cdot 10^{-16} T_e^{-3/4} \text{ m}^3\text{s}^{-1}.$$

Assume that the central stare emits 10^{48} photons per second with energy greater than 13.6 eV, and that the number density of the HII region is 100 cm^{-3}.

(Adapted from Exam, Jan., 2011)

Figure 4.