SPACE PHYSICS – ADVANCED OPTIONS

WORKSHEET ON "SOLAR WIND INTERACTION WITH PLANETARY BODIES"

The solar wind interacts with planetary bodies in a variety of ways, depending on the properties of the planetary bodies themselves. This worksheet has examples that explore the variety of interactions that occur as well as comparing and contrasting them. All of the examples are based on the additional reading you have done from "Physics of Solar System Plasmas" by Cravens and "Introduction to Space Physics", by Kivelson and Russell.

Question 1:

(i) Write down the two main reactions by which cometary ions are created in the solar wind flow.

(ii) Explain in which regions each reaction dominates.

Question 2:

(i) List the 4 main types of interactions that occur between the solar wind and planetary bodies.

(ii) Describe the properties of the planetary body that cause the specific type of interaction to occur for each of the examples listed in (i).

(iii) List some examples of solar system bodies for each of the 4 types of interactions that you listed in (i).

Question 3:

(i) In a planetary magnetosphere, the magnetopause separates the low-β plasma of the magnetosphere from the high-β plasma of the solar wind. Write down, in terms of solar wind and magnetosphere conditions, the pressure condition that holds across this magnetopause boundary.

(ii) Assuming we can write the field strength of the planet in terms of a dipole field, so that $B(r) = B_{dipole} = B_{int}$, with

$$B(r) = B_{eq}\left(\frac{R_p}{r}\right)^3$$

Where B_{eq} is the field strength at the equator on the planet's surface, R_p is the planet's radius, and r is the radial distance from the planet; derive the Chapman-Ferraro equation, taking into account the fact that the magnetopause is not just a boundary but a current layer as well and hence produces it's own magnetic field. You can also assume that we can neglect the effect of the interplanetary magnetic field in the solar wind.

(iii) Use the fact that $M_P = B_{eq}R_P^3$, together with values given in Table 7.1 of the Cravens book, as well as assuming the following parameters hold, to calculate the magnetopause stagnation point in the case of both the Earth and Jupiter. (Where M_P is the dipole moment of the planet, B_{eq} is the magnetic field strength at the equator at the planet's surface and R_P is the radius of the planet).

$u_{sw} \approx 400$ kms^{-1} at 1AU and 5.2 AU
$n_{sw} \approx 7$ cm^{-3} at 1AU and ≈ 0.4 cm^{-3} at 5.2 AU.

(iv) Are the values of R_{mp} obtained for the Earth and Jupiter reasonable and if not explain why this is the case.

(v) For Jupiter, take into account the plasma pressure effects just inside of the magnetopause assuming that the thermal pressure can be written as βp_B, where $\beta \approx 5$, and p_B is the magnetic pressure. Redo the stagnation point calculation and discuss the result in comparison to that obtained in part (iii).

Question 4:

Using Figure 7.6 from Cravens as a basis, explain some of the major differences between the dynamics of the magnetosphere of the Earth and that of Jupiter.