DEPARTMENT OF PHYSICS, UIO

FYS3610-SPACE PHYSICS

MID-TERM EXAMINATION

Date: October 6, 2008

Time of day: 15:00-18:00

Permitted aid(s): Calculating machine.

The set consists of 3 pages, with 4 Problems.

Please Note: You can write answers in English or in Norwegian!

PROBLEM 1

a) The Lorentz force on a charged particle is:

$$\vec{F}_L = q\vec{E} + q\vec{v} \times \vec{B}$$

In the absence of an electric field, demonstrate that the particle motion can be decomposed into: one constant along the magnetic field, and one accelerated perpendicular to the magnetic field.

b) Show that the gyro-radius and the gyro-frequency are given by:

$$r_c = \frac{mv_\perp}{qB} \quad \text{and} \quad \omega_c = \frac{qB}{m}$$

c) Assume a static uniform electric field along the y-axis and a static uniform magnetic field along the z-axis. Draw a sketch showing the particle trajectories separately for ions and electrons. Assume the particles are initially at rest. Show that the zeroth order drift of the guiding center is given by:

$$\vec{u}_E = \frac{\vec{E} \times \vec{B}}{B^2}$$

Vector relation: $\vec{a} \times (\vec{b} \times \vec{c}) = \vec{b}(\vec{a} \cdot \vec{c}) - \vec{c}(\vec{a} \cdot \vec{b})$ }

d) Assume a magnetic field along positive z-direction, increasing in strength along positive y. There is no electric field. Draw a sketch to show the particle trajectories separately for ions and electrons. The particles have an initial velocity along negative y. What do we call this drift?

e) Which of the two cases, c) or d), gives rise to current? Justify your answer.

PROBLEM 2

a) Draw a sketch of the undisturbed Earth magnetic field using the Earth's rotational axis as a reference. Point out the geometry of the magnetic dipole axis. What is the strength of the magnetic field near the equator and near the poles?

b) In what sense does the Earth magnetic field shield us against solar wind particles?

c) What do we mean by the "stand-off distance"? About how far out is it from the Earth's surface?

d) The Earth magnetic field are normally given in (X,Y,Z) of (H, D, Z) coordinates. Draw a figure that illustrates the components of the geomagnetic field as measured in the two coordinate systems.

PROBLEM 3

a) The E-region ionsphere is an electrical conductive layer. What controls the upper and the lower limits of this conductive layer? What is the approximate altitude range of this layer?

b) Is the electrical conductivity in the ionosphere isotropic or anisotropic? Justify your answer.

c) Height integrated currents in the ionosphere can be expressed as:

$$\begin{bmatrix} J_x \\ J_y \end{bmatrix} = \begin{bmatrix} \Sigma_P & -\Sigma_H \\ \Sigma_H & \Sigma_P \end{bmatrix} \begin{bmatrix} E_x \\ E_y \end{bmatrix}$$

Describe the parameters involved. Assume an east-west extended arc, that Σ_H and Σ_P are both zero outside the arc, that there is no field aligned current, and that E_y is the same inside and outside the arc. Prove that the current along the arc then is given as

$$J_y^A = \left[\frac{\left(\Sigma_H^A\right)^2}{\Sigma_P^A} + \Sigma_P^A \right] \cdot E_y$$

d) Draw a figure, and illustrate the direction of the magnetic field disturbance on the Earth surface directly underneath the "auroral electrojet" in c).

PROBLEM 4

$$\nabla \times \vec{B} = \mu_0 \vec{j} \qquad (4.1)$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \qquad (4.2)$$

$$\vec{j} = \sigma(\vec{E} + \vec{v} \times \vec{B}) \qquad (4.3)$$

a) What are the well-known names of Eqs. 4.1-4.3. Define the parameters involved.

b) Derive and expression for $\frac{\partial \vec{B}}{\partial t}$ and show that the magnetic Reynold's number is given by $R_m = \mu_0 \sigma\, vL$.

c) Discuss the physical implications of the $R_m << 1$ and $R_m >> 1$.

d) Make a brief discussion of the frozen-in-field concept. Give an example where the frozen-in-field concept breaks down.

Vector relation: $\nabla \times (\nabla \times \vec{A}) = \nabla(\nabla \cdot \vec{A}) + \nabla^2 \vec{A}$