DEPARTMENT OF PHYSICS, UIO

FYS3610-SPACE PHYSICS

MID-TERM EXAMINATION

Date: October 28, 2003

Time of day: 10:00-12:00

Permitted aid(s): Calculating machine.

The set of exercises consists of 3 pages, with 3 exercises.

EXERCISE 1

a) Include a gravitational force into the momentum equation of the MHD equations, assuming that the gravitational acceleration $\vec{g}$ is in the direction perpendicular to the magnetic field lines.

$$\rho\left(\frac{\partial}{\partial t}\vec{u} + \vec{u}\cdot\nabla\vec{u}\right) = -\nabla p + \vec{J}\cdot\vec{B} + \rho\vec{g},$$

where ρ is the mass density, p is the pressure, J the current density and B the magnetic field.

Let the plasma density and temperature be uniform over all space. Demonstrate that under equilibrium conditions, there must be a net current density $\vec{J}$, in the plasma. Find the magnitude and direction of $\vec{J}$.

b) Consider the MHD momentum equation as in problem a), now with the gravitational field vanishing, but let the plasma be inhomogeneous in the direction perpendicular to B. Demonstrate that under equilibrium conditions, there must be a net current density $\vec{J}$, in the plasma also in this case. Find the magnitude and direction of $\vec{J}$.

c) Assume we have a stationary magnetosheath in equilibrium. Let the velocity of the solar wind increase, with the solar wind density remaining constant. In which direction will the position of the magnetosheath change, if it changes at all?
   i) Towards the Sun,
   ii) away from the Sun,
   iii) or will the position remain unchanged?

EXERCISE 2

a) Draw a sketch of the height variation of temperature in the Earth's atmosphere and explain in general terms what are the physical mechanisms responsible for this structure.

b) Derive the barometric equation for an isothermal atmosphere and explain the physical meaning of the term scale height.

c) What do we mean by an adiabatic temperature variation with height? What are the criteria for a stable and unstable atmosphere in relation to this gradient?

d) Draw a sketch of the height variation of electron density in the ionosphere and identify the ionospheric layers. What the most important production mechanisms for these layers during quiet and disturbed conditions?

EXERCISE 3

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

b) 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.

c) Figure 1 shows the energy levels of atomic oxygen. Draw typical altitude profiles for the 630.0 nm and the 557.7 nm emission lines (night-time or day-time) and comment on the main difference.

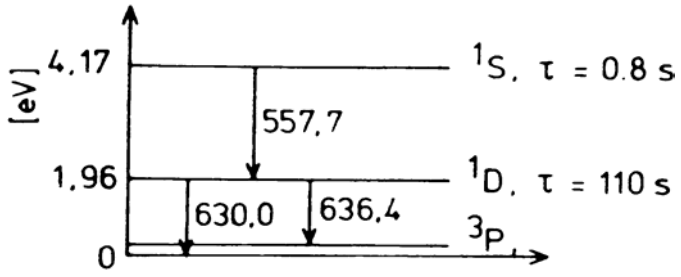

Figure 1

d) 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

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

What do we call this current near mid-night.