UNIVERSITETET I OSLO

Det matematisk-naturvitenskapelige fakultet

MID-TERM EXAMINATION

Course: Fys 3610 Space Physics

Date: October 11, 2004

Time of day: 14:30-17:30

Permitted aid(s): Calculator (with emptied memory/ off-line).

The set of examination consists of 5 Pages and 4 Problems.
Please make sure that you have a complete set.

Choose 3 of 4 Problems.

PROBLEM 1 - PARTICLE MOTIONS

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 a an electric field, show that the particle's motion can be resolved into to components: one constant along the magnetic field and one periodic, 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 showing 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 - SUN, SOLAR ACTIVITY AND MAGNETIC STORMS

a) What do we mean by a coronal hole (magnetic field structure, temperature, x-ray image appearance)?

b) What do we mean by a CME?

c) How are the CMEs observed?

d) What do we mean by a halo CME?

e) Indicate the magnetic field structure and the filament position in the (i) Kippenhahn-Schluter (K-S) and (ii) Kuperus and Raadu (K-R) models of filaments (prominences).

f) Write down the equation describing the stability of the filament in the K-S model. Alternatively: what forces (3) are important for the stability of the filament in the K-S model?

g) What type of force is driving the CMEs (the plasma ejection)?

h) What are the characteristic properties of filaments/prominences (density, temperature, magnetic field intensity) compared to the surrounding plasma?

i) What is the role of magnetic reconnection in eruptive filaments/CMEs (cf. the K-R model)?

j) What do we mean by interplanetary CMEs (ICMEs)?

k) What is the magnetic field structure of ICMEs (interplanetary magnetic clouds)?

l) What is the relationship between CMEs and magnetic storms on Earth?

m) What is the expression for the geoeffective interplanetary electric field (E_I)?

n) What is the lower limit of E_I for the excitation of major magnetic storms on Earth (Dst < - 100 nT)?

o) Describe (i) the content of the Dessler - Parker - Sckopke relation for the magnetic deflection at the Earth's surface generated by the ring current (the magnetic disturbance expressed by the Dst index) and (ii) the different steps in the derivation of the formula.

PROBLEM 3 - THE SOLAR WIND

a) Which observations before the space era indicated the existence of a continuous solar wind?

b) When was the first continuous solar wind observations made?

c) What are the basic elements of Parker's solar wind model?

d) Indicate typical values for plasma density and temperature in the corona?

e) Explain the different forces acting on a plasma volume element in the corona and the terms in the radial momentum equation for the solar wind given as:

$$\rho u\left(\frac{\partial u}{\partial r}\right) = -\frac{\partial p}{\partial r} - \frac{\rho MG}{r^2}$$

f) What force is responsible for the corona-solar wind expansion?

g) Describe (in words) how one can derive an expression for the radial velocity profile (u (r)) in the corona - solar wind model of Parker.

h) List typical values of these solar wind parameters at 1 AU (near Earth):
(1) speed, (2) density, (3) magnetic field (IMF) intensity.

i) What are the range of solar wind speed values in these three solar wind categories: (1) slow wind, (2) fast wind (HSS), and (3) in CMEs.

j) What is the relation between coronal holes and high-speed streams in the solar wind?

k) Explain the different terms in the energy equation for the solar wind given as:

$$\rho u A\left[\frac{1}{2}u^2 + \frac{\alpha}{\alpha - 1}\frac{p}{\rho} - \frac{GM}{r}\right] = const$$

l) Give a qualitative estimate of the relative importance of the various terms in the solar wind energy equation at these two locations: (1) the base of the solar corona, and (2) at 1 AU (at the distance of the Earth). Describe energy conversion taking place during the expansion from corona to Earth.

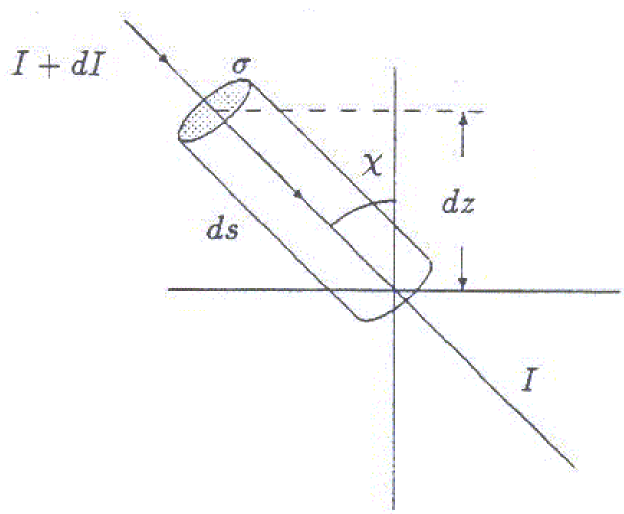
PROBLEM 4 - THE EARTH'S ATMOSPHERE

a) Draw a sketch of the height variation of temperature in the Earth's atmosphere from sea level to 150 km. Explain in general terms what are the physical mechanisms responsible for this structure. Annotate the different regions of the atmosphere by name.

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 atmosphere? In which of the two cases do we have a convective instability: i) when $\frac{\partial \rho}{\partial z} < \frac{\partial \rho}{\partial z}_{|ad}$ or ii) when $\frac{\partial \rho}{\partial z} > \frac{\partial \rho}{\partial z}_{|ad}$? Draw a sketch and justify your answer.

d) Assume monochromatic light at a sloping incidence with a horizontally stratified atmosphere as shown in the figure below.



Set up an expression for the absorbed radiation in an element ds of this radiation path. Define the parameters involved. Show that the intensity of incoming radiation varies with solar zenith angle as: $I = I_\infty e^{-\tau \sec \chi}$. Define τ and explain the meaning of this parameter.

e) The ion production rate for an exponential atmosphere can be written as:

$$q(\chi, z) = \frac{I_\infty \eta}{H} \tau \cdot e^{-\tau \sec(\chi)}$$

Show that the maximum production rate can be expressed as:

$$q_m(\chi, z_m) = \frac{I_\infty \eta \cos \chi}{eH} = q_m(0, z_{m0}) \cos \chi$$

Sketch a graph demonstrating how maximum ion production varies with zenith angle.

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