DEPARTMENT OF PHYSICS, UIO

FYS3610-SPACE PHYSICS

MID-TERM EXAMINATION

Date: October 10, 2005

Time of day: 13:30-15:30 (2 hours!)

Permitted aid(s): Calculating machine.

The set consists of 4 pages, with 3 Problems.

NOTE: At page 4 you find a Table with some numbers and equations that might be useful.

Problem 1

THE ATMOSPHERE

a) The Earth atmosphere is subdivided in regions according to the temperature altitude profile. Draw a temperature versus altitude profile with realistic scales. Annotate the different regions by name. Point out the heat sources along this profile.

b) The barometric equation for an isothermal atmosphere is given as:

$$p = p_0 \cdot e^{-\frac{mg}{kT}z}$$

Show how to derive this equation. Define the scale height. What is the typical scale height in the meteorological region?

c) Draw a figure that qualitatively demonstrates the Chapman layer variations with altitude z and zenith angle χ .

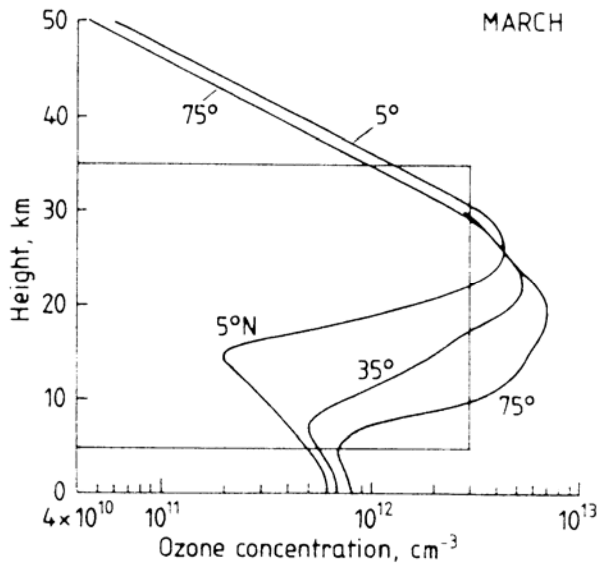

Figure 1

d) Describe Figure 1 above. Explain the latitude variation of the peak magnitude and peak altitude.

Problem 2

THE EARTH MAGNETIC FIELD AND PARTICLE MOTION

The Lorentz force on a charged particle is given as :

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

a) In the absence of an electric field, show that a charged particle's motion can be resolved into two components: one along the magnetic field and one perpendicular to the magnetic field.

b) Show that the gyro gyro radius is given by $r_c = \frac{mv_\perp}{qB}$ and that the gyrofrequency is given by $\omega_c = \frac{qB}{m}$

c) Calculate the gyrofrequencies (in hertz) of proton and an electron in a 100-nT field, a 1000 nT field and a 10.000 nT field. At roughly what distances from Earth centre can these gyrofrequences be found in the equatorial plane (see Table for information about the Earth's magnetic field)?

d) What is the gyroradius of a proton moving with transverse to a 100 nT magnetic field at $2\text{x}10^5 \text{ms}^{-1}$? How does this distance compare with the distance in the equatorial plane over which the Earth's dipole field changes from 100 nT to 200 nT (a factor 2)?

Problem 3

THE SUN

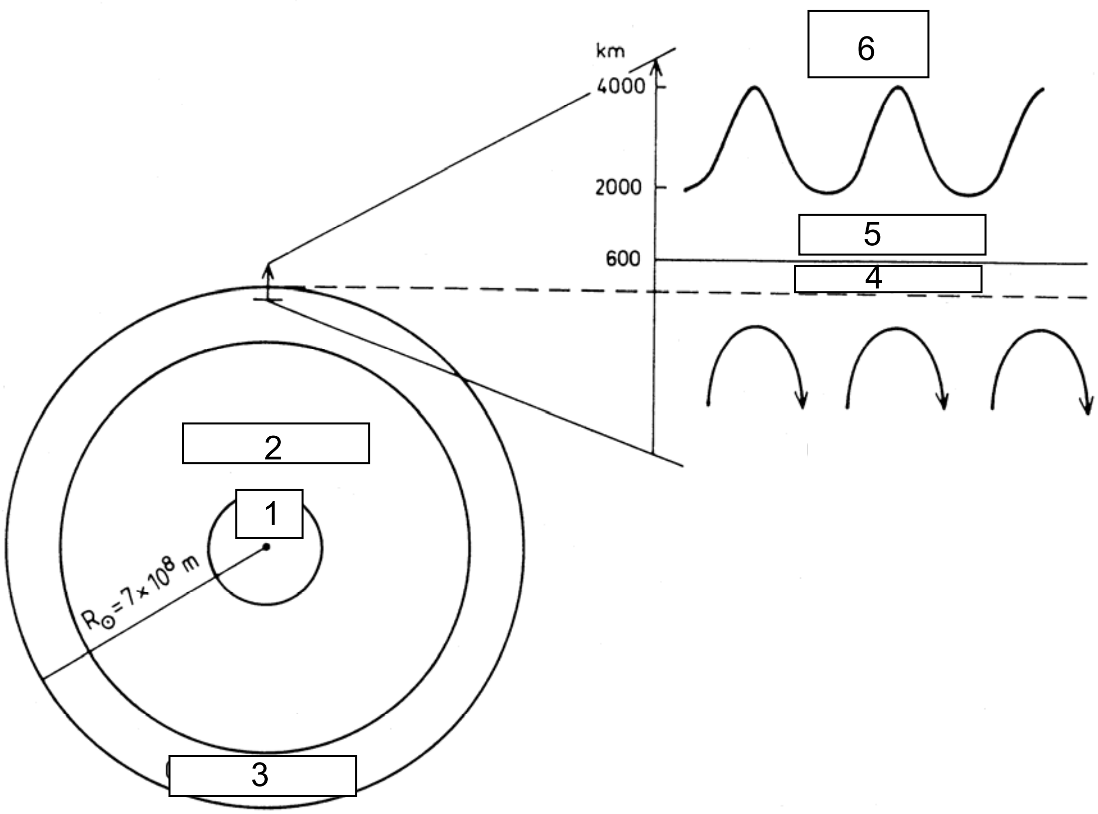

Figure 2

a) Name different regions 1- 6 in Figure 2.

b) Give a brief characteristics of sunspots (where do they occur, magnetic field, temperature,11-year cycle).

c) The solar radius is 6.960 x 10^5 km; the Sun weights 1.989 x 10^{30} kg. What is the escape velocity?

d) The Sun emits 3.9 x 10^{26} Js^{-1}. If all the energy emitted comes from fusion in the core, how much mass is burned off per second of the Sun? How long will it take to burn off 1% of the mass?

e) The total radiated power from the Sun is:

$$Q_S = 4\pi R_S^2 E_S = 3.9 \text{ x } 10^{26} \text{ W}$$

Show that the radiated energy per unit area at 1 AU (1.496 x 10^8 km) is 1380 Wm^{-2}.

List of equations and numbers:

$$E = mc^2$$

$$B_{Eq} = B_0 (\frac{R_E}{r})^3$$

$$E = -\frac{GMm}{r}$$

$$\rho = nm$$

$$a_c = \frac{v_\perp^2}{r}$$

$B_0 = 30000nT$

$R_E = 6400km$

R_S = 6.960 x 10^5 km

1 AU = 1.496 x 10^8 km

$|q| = e = 1.6 \times 10^{-19}$ C

G = 6.67 x 10^{-11} N m^2 kg^{-2}

$k = 1.38 \times 10^{-23}$ J K^{-1}

$m_p = 1.67 \times 10^{-27}$ kg

$m_e = 9.1 \times 10^{-31}$ kg

$c = 3 \times 10^8$ ms^{-1}