Tentamen i rymdfysik, 2000–10–27, kl 0900–1500

Hjälpmedel: Physics Handbook, räknare, engelska lexikon

1. A rocket has mass $m_l = 400$ kg before launch and consumes its 200 kg of fuel during the burn time $t_b = 10$ s. The exhaust velocity of the gas from the rocket motor is $\mathbf{v}_e = 2000$ m/s vertically downwards. What is the velocity of the rocket at the time $t = 30$ s? (Aerodynamic friction and variations in the gravitational force can be neglected.)

2. Describe qualitatively how the Chapman profile in the electron density is formed in the ionosphere. Start from an isothermal atmosphere with exponetially decreasing density, and consider radiation from the Sun in its zenith.

3. The electromagnetic radiation from the Sun has an intensity of 1.39 kW/m^2 at the orbit of Earth (1 AU $= 1.496 \cdot 10^{11}$ m), and the solar wind has an average density of $7 \cdot 10^6$ protons/m^3 and velocity 450 km/s. Assuming spherical symmetry and that the loss-rate is independent of the solar mass, which at present is $2 \cdot 10^{30}$ kg, estimate how many years it will take before the Sun lost all its mass.

4. An ionospheric electron has kinetic energy 10 eV when its velocity is perpendicular to the magnetic field at a point where the field strength is $B_I = 50\mu$T. This electron moves through the magnetosphere to reach the equatorial plane where the field is $B_E = 5\ \mu$T. Neglecting any electric fields and assuming that the magnetic field is stationary in time and slowly varying in space, what is the parallel velocity of the electron at the equatorial plane?

5. Derive an expression for the frequency of electrostatic plasma oscillations in an unmagnetized plasma, and calculate the plasma frequency in the ionosphere where the electron density is 10^{12} m^{-3} and most of the ions are O^+.

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6. Driven flows of plasma in the equatorial magnetosphere will cause field aligned currents connecting to the ionosphere, as shown in Figure 1. Within a layer around the equatorial plane the plasma is in a steady state driven by a force density

$$F_y(x, z) = F_0 \exp\left(-\frac{x^2}{L_x^2} - \frac{z^2}{L_z^2}\right)$$

where $F_0 = 10^{-17}$ N m^{-3}, $L_x = 50$ km and $L_z = 500$ km. Assume that the equatorial magnetic field is 50 nT, independent of x and z in the region where F_y is significant, and that the plasma density n is constant at 10^5 electrons/m^3 down to 2000 km altitude.

Using that $\mathbf{F} = \mathbf{j} \times \mathbf{B}$ and $\partial_{\mathbf{r}} \cdot \mathbf{j} = 0$ in a steady state, what is

a. —the maximum field-aligned current density leaving the equatorial generator region? (2 p)

b. —the kinetic energy of the current carrying electrons at 2000 km altitude where the magnetic field is 50 μT? You may assume that there are no perpendicular currents in the region between the generator and the ionosphere. (If you have not solved **a**, you may assume that the current leaving the equatorial region is 1 nA/m^2.) (1 p)

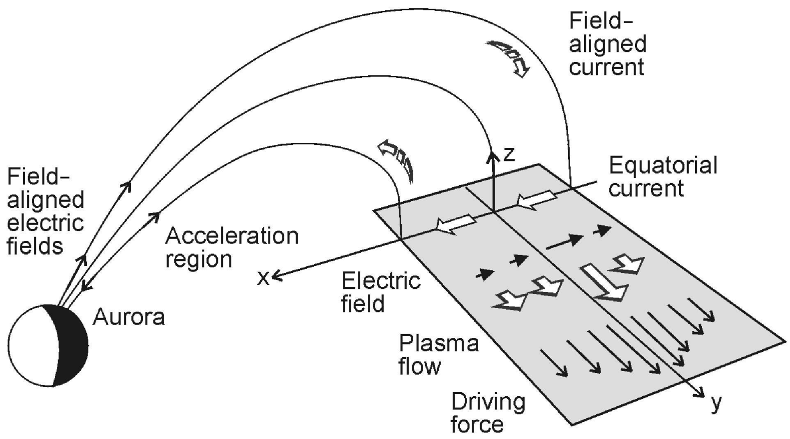

Fig. 1. Geometry of the auroral current circuit.