FYS3360

Plasma Physics

Final exam 22.1.2010

Answer four (4) of the following questions 1-5. English and Finnish are both accepted.

1. (a) List the plasma conditions and explain (briefly) their physical meaning. (4p)
   (b) Assume small perturbations of electron density and electron velocity (with zero bulk velocity) and derive the equation for plasma oscillation frequency by applying continuity equation and Maxwell's first law. (2p)

2. (a) Let's consider Earth's ionospheric plasma and assume it consists of electrons and singly charged oxygen ions. Calculate the electron and O^+ ion guiding center drift velocities caused by the gravitational drift at the altitude of 500 km on Earth's equatorial plane. Assume that the magnetic field strength is $3 \cdot 10^{-5}$ T. (Radius of Earth is 6371 km. Atomic mass number of Oxygen is 16). (2p)
   (b) Calculate the current density (current / unit area) of the ring current caused by the gravitational drift. Assume electron density of 10^6 cm^{-3}. (2p)
   (c) What is the magnitude and direction of electric field causing an $\vec{E} \times \vec{B}$ - drift canceling the electron gravitational drift? (1p)
   (d) How does this electric field affect the O^+ drift and the density of the ring current? (1p)

3. (a) Explain what is a magnetic bottle and why it can be used for trapping of charged particles. (3p)
   (b) Consider a magnetic bottle with $B(z) = B_0\left(1 + (z/a_0)^2\right)$ where B_0 and a_0 are positive constants, and that the mirroring planes are given by $z = -z_m$ and $z = z_m$. Show that the z-component of the velocity of a charged particle (with mass m) is given by $v_{\parallel}(z) = \left(\frac{2|\vec{\mu}|B_0}{m}\right)^{1/2}\left[\left(\frac{z_m}{a_0}\right)^2 - \left(\frac{z}{a_0}\right)^2\right]^{1/2}$, where the vector μ is the magnetic moment of the charged particle. (3p)

4. (a) Explain how capacitive and inductive plasma-RF coupling differ from each other. (3p)
   (b) Explain why and how plasma diamagnetism can be applied as a diagnostics method. (3p)

5. True or False (T/F). Note: for each question (i – xii) correct answer equals to +0.5 points, wrong answer equals to -0.5 points, no answer at all equals to 0p. However, minimum score from this exercise is 0 (you cannot lose points gained in any other exercise by failing this one). No explanations are required, answer simply T or F.

   (i) Gradient-curvature drift helps to confine plasma in Tokamak-type fusion devices.
   (ii) If the perpendicular (with respect to external magnetic field) velocity component of a charged particle increases while the parallel component remains unaltered, the particle confinement in magnetic bottle becomes stronger.
   (iii) Collisions between plasma particles can affect the ionization degree of the plasma.
   (iv) In 1 T magnetic field protons whose collision frequency is 100 MHz can be considered magnetically confined.
   (v) For a given ion species charge exchange cross section increases with increasing ion charge.
   (vi) MHD is a fluid theory.
   (vii) Alfven wave does not cause fluctuations of plasma pressure or density.
   (viii) When EM-wave encounters a cut-off, transmission cannot occur.
   (ix) Optical diagnostics (spectroscopy) can be used for measuring ion temperature in plasma.
   (x) Langmuir-probe can be used for measuring ion temperature in plasma.
   (xi) In D-T fusion the fusion energy is carried away mostly by charged particles.
   (xii) Gravity is the plasma confinement "mechanism" in stars.