Indian Institute of Technology, Delhi

Department of Physics

EPL208 Electrodynamics and Plasmas

Second Semester 2013-2014

Minor-II — Marks: 20

Duration: 1 hour — Date: 24 March 2014

1. (a) Suppose the axial magnetic field in a magnetic mirror bottle is given by

$$\boldsymbol{B}(z)=B_0\left[1+\left(\frac{z}{a_0}\right)^2\right]\hat{z}$$

Where B_0 and a_0 are positive constants and the mirror planes are at $z=\pm z_m$. For a charge particle of mass m just trapped, calculate the z component of the particle velocity. Also show that the particle oscillates between the mirror planes with a frequency

$$\omega=\sqrt{\frac{2\mu B_0}{m a_0^2}}$$

(b) Suppose a positively charged particle is moving in a magnetic field produced by a long straight steady current carrying conductor and a uniform electric field applied parallel to the conductor. Draw appropriate diagram and give the directions of $\boldsymbol{E}\times\boldsymbol{B}$, Grad-$\boldsymbol{B}$ and curvature drifts.

(5+3)

2. A cylindrically symmetric isothermal plasma column of radius r_0 placed in a uniform axial magnetic field $\boldsymbol{B}=B_0\,\hat{z}$ has a radial density distribution

$n(r)=n_0\exp\left(-\frac{r^2}{r_0^2}\right)$. Also $n_i=n_e=n_0\exp\left(\frac{e\phi}{kT_e}\right)$.

(a) Calculate the $\boldsymbol{E}\times\boldsymbol{B}$ and electron diamagnetic drift and show that they are equal and opposite. (b) Find the diamagnetic current density as a function of radius r.

(5)

3. (i) A simple model of the ionosphere may be formulated by assuming that the plasma density increases linearly from zero at height z_0 to 10^{12} m^{-3} at height z_1 and then decreases linearly to zero at height $2z_1$-z_0. A uniform plane wave at 1 MHz travelling directly upward encounters the ionosphere. At what height in the ionosphere this wave will be totally reflected?

(ii) By writing the linearized Poisson's equation used in the derivation of simple plasma oscillation in the form $\nabla\cdot(\varepsilon\boldsymbol{E})=0$, get an expression for the dielectric constant ε applicable to high frequency longitudinal motions.

(3+4)

Constants:

$e = 1.60\times10^{-19}$ C $\quad m_e = 9.11\times10^{-31}$ Kg $\quad \varepsilon_0 = 8.85\times10^{-12}$ F/m

$\mu_0 = 4\,\pi\times10^{-7}$ H/m $\quad c = 3.0\times10^{8}$ m/s

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