Indian Institute of Technology, Delhi

Department of Physics

EPL208 Electrodynamics and Plasmas

Second Semester 2013-2014

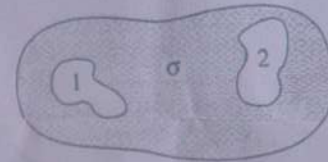
Minor-I

Duration: 1 hour

Marks: 20

Date: 08 Feb. 2014

1. (a) Two metal objects are embedded in a weakly conducting material of conductivity (σ) as shown in the Figure. Show that the resistance R between them is related to the capacitance C of the arrangement by:



$$R = \frac{\varepsilon_0}{\sigma C}.$$

(b) In a medium characterized by $\sigma = 0$, $\mu = \mu_0$, ε_0 the electric field is

$$E = 20 \sin(10^8 t - \beta z)\, a_y \ \text{V/m}$$

Calculate β and H. (3+4)

2. Calculate the (time averaged) energy density of an electromagnetic plane wave in a conducting medium. Show that the magnetic contribution always dominates. Also calculate the intensity. Given the fields

$$E(z,t) = E_0 e^{-k_I z} \cos(k_R z - \omega t + \delta_E)\hat{x}$$
$$B(z,t) = B_0 e^{-k_I z} \cos(k_R z - \omega t + \delta_E + \phi)\hat{y}$$

where, $k = k_R + i\, k_I$ is the propagation constant, $k_{R/I} = \omega\sqrt{\frac{\varepsilon\mu}{2}}\left[\sqrt{1+\left(\frac{\sigma}{\varepsilon\omega}\right)^2} \pm 1\right]^{1/2}$.

(5)

3. (i) The typical distance between two electrons in a plasma is of the order of $(n_e)^{-1/3}$. Show that the potential energy associated with bringing two electrons this close together is much less than there typical kinetic energy, so long as $n_e \lambda_D^3 >> 1$.

(ii) Two semi-infinite conducting plates form a wedge region between $\phi = \phi_1$ and $\phi = \phi_2$ where $\phi_2 > \phi_1$. In the region $\phi_1 < \phi < \phi_2$, $\rho = 0$, $\varepsilon = \varepsilon_0$, $V = V_0$ at $\phi = \phi_1$ and $V = 0$ at $\phi = \phi_2$. Find V, $\boldsymbol{E}$ in the region and charge density on the two conducting plates. (4+4)

Constants:

$e = 1.60 \times 10^{-19}$ C $\quad m_e = 9.11 \times 10^{-31}$ Kg $\quad \varepsilon_0 = 8.85 \times 10^{-12}$ F/m

$\mu_0 = 4\pi \times 10^{-7}$ H/m

$$\nabla^2 t = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial t}{\partial r}\right) + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta \frac{\partial t}{\partial \theta}\right) + \frac{1}{r^2 \sin^2\theta}\frac{\partial^2 t}{\partial \phi^2}$$

$$\nabla^2 t = \frac{1}{s}\frac{\partial}{\partial s}\left(s \frac{\partial t}{\partial s}\right) + \frac{1}{s^2}\frac{\partial^2 t}{\partial \phi^2} + \frac{\partial^2 t}{\partial z^2}$$
