Indian Institute of Technology, Delhi
Department of Physics
EPL107 – Electromagnetics
First Semester 2012-2013

Major
Duration: 2 hr.

Date 22 Nov. 2013
Marks: 50

1. (i) Four point charges $+2q$, $+q$, $-q$ and $-q$ are located at the four corners of a square with side d as shown in Fig.1. For what position of the origin will this charge configuration will have zero dipole moment?

(ii) A particle with mass m and charge q is released at a distance d from a grounded conducting plane of infinite extent. If the particle starts at rest what will be the final velocity of the particle when it hits the conducting plane?

(iii) A sphere of linear dielectric material has embedded in it a uniform free charge density ρ. Find the potential at the center of the sphere, if its radius is R and its dielectric constant ε_r.

(4+4+3)

2. (a) A symmetric core of steel with $\mu = 1000\ \mu_0$ has a uniform cross section of 4 cm^2 except in the central leg with cross section of 6 cm^2 as shown in Fig. 2. The left and the right legs have coils with current 10 A (300 turns) and 5 A (200 turns) respectively. Calculate the flux density in each leg.

(b) Calculate the force per unit length acting between two coplanar parallel wires carrying currents I_1 and I_2 and separated by a distance d.

(4+4)

3. (i) A beam of protons with a velocity of 4×10^5 m/s enters a uniform magnetic field B_z of 0.3 T. The velocity makes an angle of 60° with the magnetic field. Calculate the radius and pitch of helical path taken by the proton beam.

(ii) If B is uniform, show that $A(r) = -\frac{1}{2}(r \times B)$ is a valid vector potential.

(iii) A sphere of radius R carries a uniform polarization P and a uniform magnetization M (not necessarily in the same direction). Find the electromagnetic momentum of this configuration.

(3+4+6)

(i) The electric field in free space is given by

$$\mathbf{E} = 50\cos(10^8 t + \beta x)\hat{y} \text{ V/m}$$

Find the direction of wave propagation, calculate β and the time it takes to travel a distance of $\lambda/2$. Sketch the wave at t = 0, T/4 and T/2, where T is the time period of the wave.

(ii) A plane wave propagating in a medium has

$$\mathbf{E} = 2e^{-\alpha z}\sin(10^8 t - \beta z)\hat{y} \text{ V/m}$$

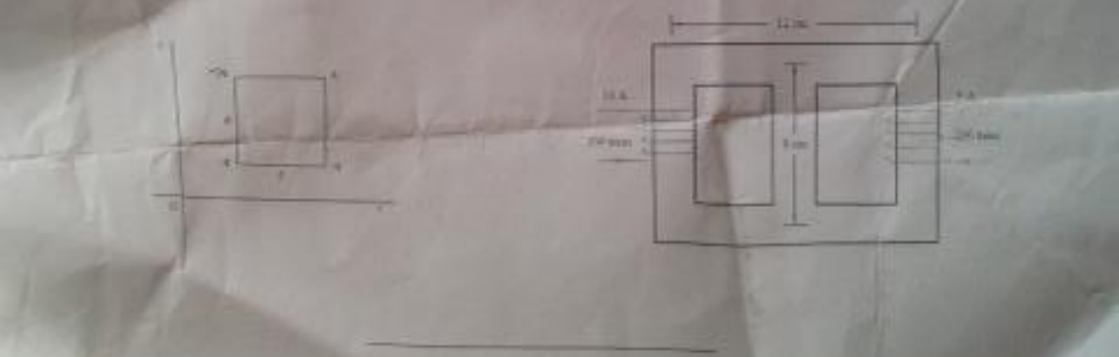
If the medium is characterized by $\varepsilon_r = 1$, $\mu_r = 20$ and $\sigma = 3$ mhos/m, find α, β and $\mathbf{H}$

(5+5)

5. (a) An electromagnetic wave is given by $E = E_0 \cos[\omega(\varepsilon\mu)^{0.5}z - t]\, a_x + E_0 \sin[\omega(\varepsilon\mu)^{0.5}z - t]\, a_y$, where E_0 is a constant. Prove that the Poynting vector is $(\varepsilon/\mu)^{0.5}E_0^2\, a_z$.

(b) For normal incidence (em wave propagating from medium 1 to medium 2) calculate (using boundary conditions) the exact reflection and transmission coefficients, without assuming $\mu_1 = \mu_2 = \mu_0$. Also confirm that $R + T = 1$.

(3+5)



Constants:

$e = 1.602 \times 10^{-19}$ C
$\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2
$\mu_0 = 4\pi \times 10^{-7}$ N/A^2
$m_p = 1.672 \times 10^{-27}$ Kg
$c = 3 \times 10^8$ m/s