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B. Tech  
CPEE 5307

FIFTH SEMESTER EXAMINATION – 2005

ELECTROMAGNETIC THEORY

Full Marks – 70

Time : 3 Hours

*The figures in the right-hand margin  
indicate marks.*



*Answer Question No. 1 which is compulsory and  
any five of the remaining questions.*

1. Answer the following : 2×10
- (i) Transform the vector  $\vec{B} = y\vec{a}_x - x\vec{a}_y + z\vec{a}_z$  into cylindrical co-ordinates.
  - (ii) Two infinitely long line charges are separated by a distance 'd'. Draw the equipotential surfaces.
  - (iii) Show that the capacitance of an isolated metallic sphere of radius R is  $4\pi\epsilon_0 R$  farads.

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- (iv) Two current elements  $I_1 d\vec{l}_1$  and  $I_2 d\vec{l}_2$  are separated by a distance  $R$ . Write the expression for the magnetic force experienced by each current element due to the other.
- (v) Write the electromagnetic boundary conditions on the surface of a perfect conductor.
- (vi) A plane uniform electromagnetic wave having electric field strength  $E = 1\text{V/m}$  at frequency  $300\text{ MHz}$  is incident normally on a copper slab having conductivity  $\sigma = 5.8 \times 10^7\text{ mhos/m}$ . Determine the depth of penetration  $\delta$ .
- (vii) A small loop of conducting wire carries a current  $I$ . Draw the magnetic lines of force due to it.
- (viii) An a. c. voltage  $V = V_m \sin \omega t$  is applied across a capacitor. Show that the displacement current through the capacitor is equal to the conduction current  $I$  flowing through connecting wire.

- (ix) Show that in a uniform linear array radiating broadside, the first secondary maximum (1st side lobe level) appears  $-13.5\text{ dB}$  below the principal maximum (main lobe).
- (x) Define polarization of an electromagnetic wave. Under what conditions the wave is said to be linearly polarized?

2. Four identical 3-nano coulomb charges are located at  $P_1 (1, 1, 0)$ ,  $P_2 (-1, 1, 0)$ ,  $P_3 (-1, -1, 0)$  and  $P_4 (1, -1, 0)$  in a rectangular co-ordinate frame. Find the electric field at  $P (1, 1, 1)$ . 10

3. Two co-axial conducting cylinders of radius 2 cms and 5 cms have a length of 1 m. The region between the cylinders is filled with a dielectric of  $\epsilon_{r1} = 2$  from  $r = 2\text{ cms}$  to  $r = 4\text{ cms}$  and  $\epsilon_{r2} = 3$  from  $r = 4\text{ cms}$  to  $r = 5\text{ cms}$ . Find the capacitance between the cylinders. Derive the formula you use. 10

4. (a) Develop the concept of vector magnetic potential  $\vec{A}$ . Derive the wave equation in terms of  $A$ . 5

(b) A current element  $I d\vec{l}$ , located at the origin of a rectangular co-ordinate system is lying along the z-direction. Using vector magnetic potential  $\vec{A}$  find the magnetic field intensity  $\vec{H}$  at an observation point  $P(\rho, \phi, z)$ . 5

5. (a) List all the Maxwell's equations for time varying electromagnetic field. Write also the equation of continuity. Give a physical interpretation of the equation containing displacement current density. 5

(b) A uniform plane electromagnetic wave propagating in free space is given by

$$\vec{E} = 37.7 \cos(9\pi \times 10^7 t + 0.3\pi y) \vec{a}_x \text{ V/m}$$

Find its (i) Phase shift constant  $\beta$ , (ii) Wave-

length  $\lambda$ , (iii) Phase velocity  $v_p$  and (iv) Whether it is a forward or backward propagating wave. 5

6. A vertically polarized uniform plane wave is incident at an angle of  $45^\circ$  from air on a dielectric slab of  $\epsilon_r = 4$ ,  $\mu_r = 1$  and  $\sigma = 0$ . The incident field strength is 100 mv/m at 10 MHz. Calculate the power transmitted to the dielectric slab. Is there an angle of incidence for which there will be no reflection? 10

7. Derive an expression for the electric field intensity for a halfwave centre fed dipole antenna. Draw its radiation pattern. Draw also the radiation pattern of a quarterwave monopole antenna. 10

8. Write short notes on any two : 5×2

(a) Principle of Pattern Multiplication

(b) Poynting vector and Power flow

- (c) Biot-Savart law
- (d) Method of Images
- (e) Hysteresis loop of a magnetic material.

