Code: AE-14 **Subject: ELECTROMAGNETICS AND RADIATION**

JUNE 2007

Time: 3 Hours **Max. Marks: 100**

NOTE: There are 9 Questions in all.

- **Question 1 is compulsory and carries 20 marks. Answer to Q. 1. must be written in the space provided for it in the answer book supplied and nowhere else.**
- **Out of the remaining EIGHT Questions answer any FIVE Questions. Each question carries 16 marks.**
- **Any required data not explicitly given, may be suitably assumed and stated.**

Q.1 Choose the correct or best alternative in the following: (2x10)

a. Which of the following conditions will not guarantee a distortionless transmission line?

(A) R = 0, G = 0
(B) RC = GL.
(C) Very low frequency range (R >> ωL, G >> ωC)
(D) Very high frequency range (R << ωL, G << ωC).

b. The dominant mode for rectangular waveguide is

(A) TE_{11} **(B)** TM_{11}
(C) TM_{10} **(D)** TE_{10}

c. A very small thin wire of length λ/100 has a radiation resistance of

(A) ≅ 0 Ω **(B)** 0.08 Ω
(C) 7.9 Ω **(D)** 790 Ω

d. In a certain medium $\overline{E} = 10\,\text{Cos}(10^8 t - 3y)\,\overrightarrow{a_x}$ V/m. What type of medium is it?

(A) Free space **(B)** Lossy dielectric
(C) Lossless dielectric **(D)** Perfect conductor

e. Which of the following statements is not true of waves in general?

(A) It may be a function of time only
(B) It may be sinusoidal or cosinusoidal
(C) It may be a function of time and space
(D) For practical reasons, it must be finite in extent.

f. Plane y=0 carries a uniform current of 30 $\overrightarrow{a_z}$ mA/m. At (1, 10, –2), the magnetic field intensity is

(A) $-15\ \overline{a_x}$ mA/m **(B)** $15\ \overline{a_x}$ mA/m

(C) $477.5\ \overline{a_y}$ μA/m **(D)** $18.85\ \overline{a_y}$ nA/m

g. A loop is rotating about y-axis in a magnetic field $\overline{B} = B_0 \sin\omega t\ \overline{a_x}$ Wb/m^2. The voltage induced in the loop is due to

(A) Motional emf
(B) Transformer emf
(C) A combination of motional & transformer emf
(D) None of the above

h. A parallel plate capacitor consists of two metal plates of area *A* spearated by a distance *d* and has a capacitance *C*. If another metal plate of area *A* is held parallel to either plate of the capacitor at distance *d*/2 from either plate, the new capacitance will be

(A) *C*/2 **(B)** *C*
(C) 2*C* **(D)** 4*C*

i. If $\nabla \cdot \overline{D} = \epsilon \nabla \cdot \overline{E}$ and $\nabla \cdot \overline{J} = \sigma \nabla \cdot \overline{E}$ in a given material, the material is said to be

(A) Linear **(B)** Homogeneous
(C) Isotropic **(D)** Linear & Homogeneous

j. Point charges 30 nC, –20 nC and 10 nC are located at (–1, 0, 2), (0, 0,0) and (1, 5, –1) respectively. The total flux leaving a cube of side 6m centered at the origin is

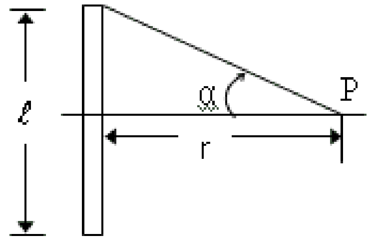
(A) –20 nC **(B)** 10 nC
(C) 20 nC **(D)** 30 nC

Answer any FIVE Questions out of EIGHT Questions.
Each question carries 16 marks.

Q.2 a. Obtain the expression of electric field of an infinite sheet of charge in xy plane with charge density ρ_S. **(8)**

b. A line of length ℓ carries charge ρ_L C/m. Show that the potential in the median plane can be written as

$$V = \frac{\rho_L}{4\pi \epsilon_0} \ln \frac{1+\sin\alpha}{1-\sin\alpha}$$



Refer to the Figure.

(8)

Q.3 a. Given two mediums having permeabilities μ_1, μ_2, prove that

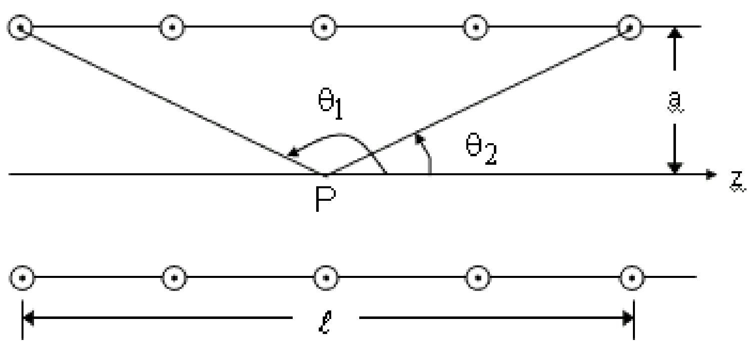
$$\frac{\tan\theta_1}{\tan\theta_2} = \frac{\mu_1}{\mu_2}$$

where θ_1 and θ_2 represent the angles that the magnetic fields make with the normal to the interface in the two mediums. **(8)**

b. A solenoid of length ℓ and radius 'a' consists of N turns of wire carrying current I, as shown in figure. Show that at point P along its axis (z-axis),

$$\bar{H} = \frac{nI}{2}\left(\cos\theta_2 - \cos\theta_1\right)\bar{a}_z$$

where n=N/ℓ, and θ_1, θ_2 are the angles subtended at P by the end turns. Also show that if ℓ >>a, at the centre of the solenoid, $\vec{H} = nI\overrightarrow{a_z}$ **(8)**



Q.4 a. Write down Maxwell's equations in integral as well as differential forms for time-varying fields. **(8)**

b. In a medium characterized by the parameters σ=0, μ_0 and ϵ_0, and an electric field given by $\bar{E} = 20\sin\left(10^8 t - \beta z\right)\bar{a}_z$ V/m, calculate β and $\vec{H}$. **(8)**

Q.5 a. Obtain an expression for the propagation constant in good conductors. Explain skin effect. **(8)**

b. A lossy dielectric has an intrinsic impedance of 200 $\angle 30°$ Ω at a particular frequency. If at that frequency, the plane wave propagating through the dielectric has the magnetic field component $\vec{H} = 10e^{-\alpha x}\cos\left(\omega t - \frac{1}{2}x\right)\overline{a_y}$ A/m, Find $\vec{E}$ and α. Determine the skin depth and wave polarization. **(8)**

Q.6 a. What are standing waves? How do they arise? Discuss their characteristics. **(8)**

b. A 30-m long lossless transmission line with Z_0=50Ω operating at 2 MHz is terminated with a load Z_L=60+j40 Ω. If the velocity of propagation on the line is 0.6 times that of light, find the following without using Smith-chart:
(i) The reflection coefficient Γ
(ii) The standing wave ratio S
(iii) The input impedance **(8)**

Q.7 a. What is a cavity resonator? Derive an expression for the frequency of oscillation of a rectangular cavity resonator. **(8)**

b. In a rectangular waveguide for which a=1.5cm, b=0.8cm, $\sigma = 0, \mu = \mu_0$, and $\epsilon = 4\epsilon_0$, $H_x = 2\sin\left(\frac{\pi x}{a}\right)\cos\left(\frac{3\pi y}{b}\right)\sin\left(\pi \times 10^{11} t - \beta z\right)$ A/m

Determine
(i) The mode of operation
(ii) The cutoff frequency
(iii) The phase constant β
(iv) The intrinsic wave impedance η **(8)**

Q.8 a. Explain the principle of a phased array, and write a note on the log-periodic dipole array. **(8)**

b. A magnetic field strength of 5μA/m is required at a point $\theta = \frac{\pi}{2}$, 2 km from an antenna in air. Neglecting ohmic loss, how much power must the antenna transmit if it is
(i) A Hertizian dipole of $\frac{\lambda}{25}$
(ii) A half-wave dipole
(iii) A quarter-wave monopole. **(8)**

Q.9 a. Explain Poisson's and Laplace's equations with suitable applications. **(8)**

b. The surface of the photoconductor in a xerographic copying machine is charged uniformly with surface charge density ρ_S as shown in figure. When the light from the document to be copied is focused on the photoconductor, the charges on the lower surface combine with those on the upper surface to neutralize each other. The image is developed by pouring a charged black powder over the surface of the photopowder, which is later transferred to paper and melted to form a permanent image. Determine the electric field below and above the surface of a photoconductor. **(8)**