Sheet No.1

NATIONAL INSTITUTE OF TECHNOLOGY, KURUKSHETRA
THEORY EXAMINATION
Question Paper

Roll No. ____________

Month and Year of Examination : **DEC. 2024**
Programme : **B.Tech** Semester: **3rd**
Subject: **Field and Waves**
Course No: **ECPC-204** Maximum Marks: **50**
Number of Questions to be Attempted: **5** Time Allowed: **3 Hrs.**
Total No. of Questions: **6** Total No. of Pages Used: **3**

Unless stated otherwise, the Symbols have their usual meanings in context with the Subject. Assume suitably and state, additional data required, if any.
The Candidates, before starting to write the solutions, should please check the Question Paper for any discrepancy, and also ensure that they have been delivered the question paper of **right course no.** and right subject title.

Note: Attempt any five questions carrying equal marks.

1a. Given a vector function $\mathbf{F} = \mathbf{a}_x(3y - c_1 z) + \mathbf{a}_y(c_2 x - 2z) - \mathbf{a}_z(c_3 y + z)$.
   i. Determine the constants c_1, c_2 and c_3 if $\mathbf{F}$ is irrotational.
   ii. Determine the scalar potential function V whose negative gradient equals $\mathbf{F}$. **3**

1b. A finite line charge of length L carrying uniform line charge density ρ_l is coincident with x - axis.
   i. Determine V in the plane bisecting the line charge.
   ii. Determine $\mathbf{E}$ from ρ_l directly by applying Coulomb's law.
   iii. Check the answer in part (b) with $-\nabla V$. **4**

1c. Determine the values of the following products of base vectors i) $\mathbf{a}_R \times \mathbf{a}_z$ ii) $\mathbf{a}_\theta \cdot \mathbf{a}_z$ iii) $\mathbf{a}_z \times \mathbf{a}_\theta$ **3**

2a. A charge Q is distributed uniformly over an $L \times L$ square plate. Determine V and $\mathbf{E}$ at a point on the axis perpendicular to the plate and through its center.

OR

Determine the $\mathbf{E}$ field both inside and outside a spherical cloud of electrons with a uniform volume charge density $\rho = -\rho_0$ (where ρ_0 is a positive quantity) for $0 \le R \le b$ and $\rho = 0$ for $R > b$ by solving Poisson's and Laplace's equation for V **4**

2b. Derive Poisson's and Laplace's equation for electric scalar potential and write the Laplacian equation in three coordinate systems. **3**

2c. Derive equation of continuity in point form and show that it leads to the definition of KCL. **3**

3a. Explain a boundary value problem in Cartesian coordinates with the help of suitable mathematics and a practical application.

OR

What is the quantity in magnetostatics that is analogous to scalar electric potential. Explain its physical significance and the reasons of it not being used frequently. **4**

3b. Fig. 1 shows an infinitely long solenoid with air core having a radius b and n closely wound turns per unit length. The windings are slanted at an angle α and carry a current I. Determine the magnetic flux density both inside and outside the solenoid.

Fig. 1

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4a. Derive the general wave equations for $\mathbf{E}$ and $\mathbf{H}$ in a non-conducting simple medium where a charge distribution ρ and a current distribution $\mathbf{J}$ exist. Convert the wave equations to Helmholtz's equations for sinusoidal time dependence. Write the general solutions for $\mathbf{E}(R,t)$ and $\mathbf{H}(R,t)$ in terms of ρ and $\mathbf{J}$. 5

4b. For a harmonic, uniform plane wave propagating in a simple medium, both $\mathbf{E}$ and $\mathbf{H}$ vary in accordance with the factor $e^{-j\mathbf{k}\cdot\mathbf{R}}$. Show that the four Maxwell's equations for uniform plane wave in a source-free region reduce to the following:

i. $\mathbf{k}\times\mathbf{E}=\omega\mu\mathbf{H}$

ii. $\mathbf{k}\times\mathbf{H}=-\omega\varepsilon\mathbf{E}$

iii. $\mathbf{k}\cdot\mathbf{E}=0$

iv. $\mathbf{k}\cdot\mathbf{H}=0$ 5

5a. State and prove Poynting theorem. Explain its significance and show that the instantaneous Poynting vector of a circularly polarized plane wave propagating in a lossless medium is a constant that is independent of time and distance. 5

5b. Discuss the behavior of electromagnetic waves upon normal incidence on the surface of a perfect dielectric. Also derive the necessary parameters used for characterizing an interface. 5

6a. In the derivation of the approximate formulas of γ and Z_0 for low-loss lines all terms containing the second and higher powers of $R/\omega L$ and $G/\omega C$ are neglected in comparison with unity. At lower frequencies, better approximation is required, hence derive the new formulas for γ and Z_0 that retains terms containing $(R/\omega L)^2$ and $(G/\omega C)^2$. Also obtain the corresponding expression for phase velocity. 3

6b. The characteristic impedance of a given lossless transmission line is $75\,\Omega$. Use a Smith chart to find the input impedance at 200 MHz of such a line that is

40

232.5 Ω

i. 1 m long and open circuited
ii. 0.8 m long and short circuited
iii. Determine the corresponding input admittances also. 4

6c. Derive **TE** mode field expressions in a rectangular waveguide. Also give expressions for cut-off frequency and corresponding wavelength. Explain which mode is the dominant mode and reason thereof.

OR

Write a short note on cavity resonator and explain its practical significance with the help of an example. 3