Time: 3 Hours **Marks: 100**

N.B. : (1) **All** questions are **compulsory**.
(2) **Figures** to the **right** indicate **full** marks.
(3) Draw **neat** diagrams wherever **necessary**.
(4) Symbols have usual meaning unless otherwise stated.
(5) Use of **non-programmable** calculator is allowed.

Q1 Attempt any **two:---**

(i) Write the general properties of Laplace's equation in one dimension, two dimensions and three dimensions. **10**

(ii) Find the potential of a uniformly charged spherical shell of radius **R** for points inside the sphere. **10**

(iii) Suppose a point charge **q** is held a distance **d** above an infinite grounded conducting plane. Obtain an expression for the electrostatic energy stored in the field. **10**

(iv) Suppose a point charge **q** is held a distance **d** above an infinite grounded conducting plane. Derive an expression for the electrostatic field near the plane. **10**

Q2 Attempt any **two:---**

(i) Obtain an expression for the potential due to bound charges for a polarised dielectric in terms of $\boldsymbol{\sigma_b}$ $\boldsymbol{and}$ $\boldsymbol{\rho_b}$. **10**

(ii) In a linear isotropic homogeneous dielectric, $\vec{P}$ and $\vec{D}$ are both proportional to field vector $\vec{E}$. Show that $\vec{\nabla} \times \vec{P}$ is non null at the interface between dielectrics. **10**

(iii) For non-uniform current distribution $\vec{J}(\vec{r'})$ obtain an expression for divergence of magnetic field $\vec{B}$. **10**

(iv) Prove the differential form of Ampere's law by considering an infinite straight current carrying wire. **10**

Q3 Attempt any **two:---**

(i) Explain the term magnetization and obtain the expression for vector potential due to magnetized object in terms of bound currents. **10**

(ii) Show that energy stored in magnetic field is given as $\boldsymbol{W = \frac{1}{2\mu_0}\int_{All\ space} B^2 d\tau}$ **10**

(iii) Considering the charging of a parallel plate condenser show how displacement current solves the problem of failure of Ampere's law. **10**

(iv) Explain the terms Magnetic susceptibility and permeability. Describe in brief the deceptive parallel between equations $\boldsymbol{\nabla \times \vec{H} = J_f}$ and $\boldsymbol{\nabla \times \vec{B} = \mu_0 J}$ **10**

Q4 Attempt any **two:---**

(i) Show that for electromagnetic field, **10**

$$\frac{dW}{dt} = -\frac{dU_{em}}{dt} - \oint_S \bar{S} \cdot d\bar{a}$$

Symbols have their usual meanings.

(ii) For an electromagnetic wave travelling in a medium of refractive index $\boldsymbol{n_1}$ along z – axis, incident on a medium of refractive index $\boldsymbol{n_2}$, show that $\boldsymbol{R + T = 1}$ where $\boldsymbol{R}$ is reflection coefficient and $\boldsymbol{T}$ is transmission coefficient. Consider the case of normal incidence. **10**

(iii) What is wave equation? Show that electric and magnetic fields satisfy the wave equations in vacuum. **10**

(iv) For an electromagnetic plane wave, show that the electric field and magnetic field are perpendicular to each other. **10**

Q5. Attempt any **four:---** **20**

(i) Determine electric field due to potential $\mathbf{V= 3x^2 + 4y^4 + 5z^4.}$ **05**

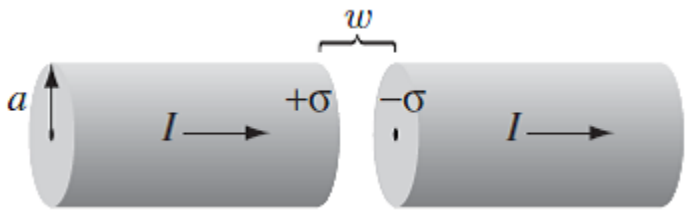
(ii) A long cylinder carries a charge density that is proportional to the distance from the axis: $\rho = \mathbf{ks}$, for some constant k. Find the electric field inside the cylinder. **05**

(iii) Show that for a given linear, isotropic homogeneous dielectric, the dielectric constant is given by an expression $\boldsymbol{k = \frac{E_0}{E}}$, where $\boldsymbol{E_0}$ **is** polarising field and E is the total electric field in the dielectric. **05**

(iv) A long solenoid carrying a current **2.5 A** is bent into toroid of mean radius **5 cm**. Its windings consist of **1000 turns**. Find the flux density at a point **(i)** inside the core of the toroid **(ii)** inside the central circumference of the toroid and **(iii)** outside the core of the toroid. **05**

(v) The magnetic susceptibility of a linear medium is $\mathbf{8 \times 10^{-5}}$. An auxiliary field $\vec{\boldsymbol{H}} = \mathbf{2 \times 10^5}\ \boldsymbol{A/m}$ along **z** axis is applied. Find the magnetization $\vec{\boldsymbol{M}}$ and the magnetic field $\vec{\boldsymbol{B}}$. ($\boldsymbol{\mu_0 = 4\pi \times 10^{-7}}\ \boldsymbol{N/A^2}$.) **05**

(vi) A thick wire of radius $\boldsymbol{a}$, carries a constant current $\boldsymbol{I}$, uniformly distributed over its cross section. A narrow gap in the wire, of width $\boldsymbol{w} << \boldsymbol{a}$, forms a parallel-plate capacitor as shown below. Find the magnetic field in the gap, at a distance $\boldsymbol{s} < \boldsymbol{a}$ from the axis. **05**



(vii) Write down the expressions for reflected and transmitted amplitude for an oblique incident. Explain each term and get an expression for Brewster's angle. **05**

(viii) Find from Poynting's flow, intensity of magnetic field in air at a distance of **500 cm** from a radiating source of **100 kW**. Take $\sqrt{\frac{\mu_o}{\varepsilon_o}} = \mathbf{377\Omega}$. **05**

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