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Name of Course : **B.Sc. Hons. (Physics)_NEP:UGCF-2022**
Semester : **V**
Name of the Paper : **Electromagnetic Theory**
Unique Paper Code : **2222013501**
Duration: 3 Hours

Maximum Marks: 90

(Write your Roll No. on the top immediately on receipt of this question paper.)

Question No. 1 is compulsory.
Answer any **four** of the remaining **five.**
Use of non-programmable calculator is allowed.

1. Attempt any 6 parts of the following: **6×3=18**

(i) Show that the time average Poynting vector for time varying fields is given by:

$$\langle \vec{S} \rangle = \frac{1}{2} Re\,(\vec{E} \times \vec{H}^*)$$

(ii) The electric field intensity for an electromagnetic wave is expressed as

$$\vec{E} = 120 \sin(10^{11} t)\, \hat{\imath}\, V/m$$

Calculate the magnitude of displacement current density and the conduction current density. Given: σ =8.0 S/m and ε_r=1.

(iii) A light beam is incident from denser medium (n_1=2.0) on a rarer medium (n_2=1). Plot the reflection coefficients for the parallel and perpendicular components as a function of the angle of incidence.

(iv) What will be the minimum thickness of a calcite plate that would convert a plane polarized light of wavelength 8000 Å into circularly polarized light? (Given: n_o=1.5533 and n_e =1.5443).

(v) Show that if the electric field of the incident wave lies in the plane of incidence, the electric fields of the reflected and transmitted waves will also lie in the plane of incidence.

(vi) The refractive indices of quartz for right-handed and left-handed circularly polarized light of wavelength 7000 Å are 1.65207 and 1.65201 respectively. Calculate the rotation of plane of polarization of light produced by a plate of thickness 0.9 mm.

(vii) Show that a beam of plane polarized light may be regarded as composed of two equal and opposite circularly polarized light.

2. (a) State and establish Poynting's theorem for electromagnetic fields. Compare it with the equation of continuity and give an interpretation of the Poynting vector. **(10)**

(b) What are electromagnetic potentials? Discuss their non-uniqueness and hence explain the significance of gauge transformation. **(8)**

3. (a) Starting from Maxwell's equations in an isotropic, homogeneous dielectric material, show that electromagnetic waves are transverse in nature. Calculate the time average of

momentum density stored in these fields. **(12)**

(b) Calculate the intrinsic impedance and wave velocity for a conducting medium with $\sigma = 60$ MS/m and $\mu_r = 1$, at frequency of 120 MHz. **(6)**

4.(a) Derive Fresnel's relation for reflection and transmission of plane electromagnetic waves at an interface between two dielectric media when an electric vector of the incident wave is perpendicular to the plane of incidence. **(10)**

(b) A uniform plane wave is incident on planar boundary separating regions 1 and 2, with $\sigma_1 = \sigma_2 = 0$ and $\mu_{r1} = \mu_{r2} = 1$. Find the ratio of $\varepsilon_{r2}/\varepsilon_{r1}$, if 20 % of the incident wave energy is (a) reflected and (b) transmitted. (Assume normal incidence). **(8)**

5.(a) Distinguish between positive and negative crystals in terms of double refraction. How are these crystals used to make quarter wave plates? Explain how the quarter wave plate is used in producing elliptically and circularly polarized light. **(12)**

(b) Show that in an electrically anisotropic dielectric medium, the permittivity tensor is symmetric in nature. **(6)**

6. (a) Derive wave equation for $\vec{E}$ of electromagnetic wave in a symmetric planar dielectric wave guide with refractive index profile as:

$n = n_1$, $-d/2 < x < d/2$

$n = n_2$, $-d/2 > x > d/2$

($n_2 < n_1$) where d is the width of the guide.

Using the boundary conditions, obtain the eigenvalue equation for symmetric TE modes. **(12)**

(b) Find the state of polarization of electromagnetic wave having electric field vector: **(6)**

$$\vec{E} = 2\cos(\omega t - kz)\,\hat{\imath} - 2\cos\left(\omega t - kz - \frac{\pi}{2}\right)\hat{\jmath}$$

Physical Constants :

$\varepsilon_0 = 8.85\times10^{-12}$ Farad/m, $\mu_0 = 4\pi\times10^{-7}$ Henry/m

$c = 3\times10^{8}$ m/s, $m_e = 9.11\times10^{-31}$ kg