'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours 6th Semester Examination, 2022

CC13-PHYSICS

ELECTROMAGNETIC THEORY

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
All symbols are of usual significance.

GROUP-A

1. Answer any ***five*** questions of the following: 1×5 = 5

   (a) Light is incident normally on an air-glass interface and reflected back. Calculate the value of reflectance. The refractive index of glass w.r.t. air is 1.5.

   (b) Calculate the value of impedance of free space.

   (c) Write down the condition in which the incident electromagnetic wave will be transmitted without producing any reflected wave.

   (d) Find out the dimension of the quantity $\mu_0\varepsilon_0$.

   (e) Is it possible for sound waves to be polarized?

   (f) The electric field of an EM wave is given by $E_z = 10^3 \sin\pi(3\times10^6 x - 9\times10^{14} t)$. Find out the speed and time period of the EM wave.

   (g) What do you mean by the term graded-index optical fibre?

   (h) An electromagnetic wave in free space has the components of electric field as $E_x = 0,\ E_y = 0,\ E_z = E_0\cos\left(\frac{2\pi x}{\lambda} - \omega t\right)$. Find the expression for magnetic field $\vec{B}$.

GROUP-B

Answer any *three* questions of the following 5×3 = 15

2. (a) Starting from the equation of continuity and assuming Ohm's law, show that the charge density in a conductor obeys the relation $\frac{\sigma\rho}{\varepsilon} + \frac{\partial\rho}{\partial t} = 0$, where the symbols have their usual meaning. 2

   (b) Show that the displacement current in a dielectric of a parallel plate capacitor is equal to the conduction current in the connecting leads. 3

3. State and explain Fresnel's theory of optical rotation. 5

4. (a) In a medium of dielectric constant, $k = 5$, the maximum displacement current is equal to the maximum conduction current at a frequency of 1 MHz. The electric field in the dielectric medium varies harmonically with time as $\vec{E} = \vec{E}_0 e^{-i\omega t}$. Calculate the electrical conductivity of the medium. 2

(b) Two linearly polarized waves are in phase but have different amplitudes. Let these waves are represented by $\vec{E}_1(z,t) = \hat{i}A_1\cos(kz-\omega t) + \hat{j}B_1\cos(kz-\omega t)$ and $\vec{E}_2(z,t) = \hat{i}A_2\cos(kz-\omega t) + \hat{j}B_2\cos(kz-\omega t)$. Show that, $\vec{E}_1 + \vec{E}_2$ is also linearly polarized. Find the direction of polarization of $\vec{E}_1 + \vec{E}_2$. 3

5. An electromagnetic wave, polarized normal to the plane of incidence, is incident from free space on to a dielectric medium at the Brewster's angle. Show that, the reflectance is given by, $R = \left(\frac{n^2-1}{n^2+1}\right)^2$, where n is the refractive index of the dielectric medium w.r.t. free space. 5

6. (a) If n_o is the refractive index for O-rays, n_e the refractive index for E-rays, then show that the refractive index n_θ for E-rays in the direction θ with optic axis in a double refracting crystal is given by, $\frac{1}{n_\theta^2} = \frac{\cos^2\theta}{n_o^2} + \frac{\sin^2\theta}{n_e^2}$. 4

(b) What do you mean by the term optical activity of a substance? 1

GROUP-C

Answer any *two* questions of the following 10×2 = 20

7. (a) Develop the electromagnetic wave equations for a conducting medium. [Assume that, charge density $\rho = 0$]. What is the dissipative term in the wave equations? 3+1

(b) Obtain plane wave solution for a non conducting medium for electric field $\vec{E}$. 3

(c) Show that for a plane electromagnetic wave in free space, the unit vector in the direction of propagation, the electric field vector and the magnetic field vector are mutually perpendicular. 3

8. (a) Define Lorentz and Coulomb gauge. Show that under suitable conditions, vector potential $(\vec{A})$ and scalar potential (ϕ) satisfy the inhomogeneous equations $\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\vec{A} = -\mu_0\vec{J}$ and $\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\phi = -\frac{\rho}{\varepsilon_0}$. 4+4

(b) Draw a neat diagram of a plane electromagnetic wave propagating along x-direction. 2

9. (a) State and prove Poynting theorem. 5

(b) A plane polarized electromagnetic wave is incident on an interface between two dielectric media. Find the relations between the angles of incidence, reflection and refraction. 3

(c) What do you mean by the terms single mode and multimode optical fibre? 2

10. (a) Using Fresnel's laws of reflection, explain the phenomenon of total internal reflection. 5

(b) What is an evanescent wave? 2

(c) Show that the equation of continuity is contained in Maxwell's equations in electromagnetic theory. 3

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