WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 6th Semester Examination, 2021

PHSACOR13T-PHYSICS (CC13)

ELECTROMAGNETIC THEORY

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Question No.1 is Compulsory and any *two* questions from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) Show that another form of Faraday's law is

$$\vec{E} = -\frac{\partial \vec{A}}{\partial t}$$

where $\vec{A}$ is the magnetic vector potential.

(b) The conduction current density in a dielectric medium is given by $\vec{j} = 0.02\sin\left(10^9 t\right)$ Amp/m^2. Find the displacement current density if $\sigma = 10^3$ mho/m and $\varepsilon_r = 6.5$.

(c) State Poynting's theorem for electromagnetic wave.

(d) Write an expression for a linearly polarized wave of angular frequency ω moving along positive z direction having plane of vibration 60° with the x-y plane.

(e) Show that in a conductor the electric and magnetic fields are not in phase.

(f) 'The terms poor and good conductor depend on frequency'— Explain.

(g) A plane polarized wave propagates from air into a dielectric medium at Brewster's angle 75°. Find the relative permittivity ε_r.

(h) What do you mean by electromagnetic momentum density? What is its unit?

(i) An EM wave is incident normally from air on an air-glass interface. Taking refractive index of glass as 1.5, find the amplitude reflection coefficient and the percentage of total incident energy that is transmitted into glass.

(j) State and explain Malus Law.

(k) A black dot is marked on a white paper. It is then viewed through a calcite crystal from the top. How many images are expected to be seen and why?

(l) Calculate the thickness of quarter-wave plate for light of wavelength 5893Å , given n_0 = 1.544 and n_e = 1.553.

(m) Write the advantages of optical fiber over coaxial cable.

(n) 'In the microwave region the surface of a pure silver waveguide and that of a silver coated brass waveguide appear identical' – Explain.

2. (a) Given the total electromagnetic energy 4

$$W = \frac{1}{2}\int (\vec{E}\cdot\vec{D} + \vec{H}\cdot\vec{B})\, dv\,.$$

Show from Maxwell's equation that

$$\frac{\partial W}{\partial t} = \oint (\vec{E}\times\vec{H})\cdot\overrightarrow{ds} - \int (\vec{E}\cdot\vec{J})\, dv$$

(b) Assuming a source-free region, derive the following wave equation from Maxwell's Equations 3

$$\nabla^2\vec{E} = \mu\sigma\frac{\partial\vec{E}}{\partial t}$$

(c) Show that under a gauge transformation of the vector potential $\vec{A}$ and the scalar potential ϕ, the electromagnetic field vectors are invariant. 3

3. (a) Starting from the wave equation in a conductor, find the expression for 'skin depth' of a conductor in terms of its conductivity and frequency of the incident wave. 4

(b) Calculate the skin depth for radio waves of wavelength 3 m (in free space) in copper, given that σ for copper is $6 \times 10^7\ \Omega^{-1}\,\text{m}^{-1}$. 2

(c) Starting from boundary conditions satisfied by the electromagnetic fields at an interface between two dielectric media, deduce Snell's law. 4

4. (a) A plane electromagnetic wave falls obliquely on the interface between two simple dielectric media. Assuming the electric vector to be perpendicular to the plane of incidence obtain the expression for the reflection coefficient. 4

(b) Explain the phenomenon of total internal reflection from Fresnel's formula. 2

(c) How is plane polarized light obtained using double refraction in a crystal? 2

(d) Let x and y components of the electric vector of an electromagnetic wave be given by $E_x = a_1 \sin\omega t$ and $E_y = a_2 \sin(\omega t + \delta)$. Show that for $\delta = 2n\pi$ where $n = 1, 2, 3...$, the electromagnetic wave is linearly polarized. 2

5. (a) Explain the operation of a Laurent half-shade polarimeter to find the concentration of sugar solution. 3

(b) 'Dielectric waveguides do not support TEM modes' – why? 2

(c) What do you mean by numerical aperture? Obtain an expression for numerical aperture and acceptance angle of an optical fiber in terms of the refractive indices. 1+2

(d) Any initial charge density in a conductor dissipates in a characteristic time $\tau = \frac{\varepsilon}{\sigma}$. Establish this statement from Maxwell's equation. 2

N.B. : *Students have to complete submission of their Answer Scripts through E-mail / Whatsapp to their own respective colleges on the same day / date of examination within 1 hour after end of exam. University / College authorities will not be held responsible for wrong submission (at in proper address). Students are strongly advised not to submit multiple copies of the same answer script.*

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