2023

PHYSICS

Paper : PHYHC6136

(Electromagnetic Theory)

Full Marks : 60
Pass Marks : 24

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct option (any *five*) : 1×5=5

(a) Ampere's law represented by the equation $\vec{\nabla} \times \vec{H} = \vec{J}$ holds good for

(i) alternating current

(ii) transient current

(iii) steady-state current

(iv) leakage current

(b) Which one of the following represents Poynting vector?

(i) $\vec{S} = \vec{B} \times \vec{J}$

(ii) $\vec{B} = \vec{S} \times \vec{E}$

(iii) $\vec{\nabla} \times \vec{B} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$

(iv) $\vec{S} = \vec{E} \times \vec{B}$

(c) The direction of propagation of electromagnetic wave is given by

(i) $\vec{E} \cdot \vec{B}$

(ii) $\vec{E}$

(iii) $\vec{B}$

(iv) $\vec{E} \times \vec{B}$

(d) The wave impedance of free space is

(i) 0

(ii) 376·6 Ω

(iii) 37·66 Ω

(iv) 3·76 Ω

(e) For normal incidence, the Fresnel's equation is

(i) $\frac{E_{or}}{E_{oi}} = \frac{n_2}{n_1}$

(ii) $\frac{E_{or}}{E_{oi}} = \frac{n_1}{n_2}$

(iii) $\frac{E_{or}}{E_{oi}} = \frac{n_2 - n_1}{n_2 + n_1}$

(iv) $\frac{E_{or}}{E_{oi}} = \frac{2n_1}{n_1 + n_2}$

(f) The path difference produced by quarter-wave plate between ordinary and extraordinary wave is

(i) λ

(ii) $\frac{\lambda}{2}$

(iii) $\frac{\lambda}{4}$

(iv) $\frac{\lambda}{8}$

(g) The fundamental form of calcite crystal is

(i) rhombohedron

(ii) tetrahedron

(iii) cuboid

(iv) cylindrical

(Turn Over

(h) If k is the dielectric constant of a non-conducting medium, the refractive index of the medium is

(i) $\sqrt{k}$

(ii) $\sqrt{\frac{1}{k}}$

(iii) $\frac{1}{k}$

(iv) None of the above

(i) The thickness of a half-wave plate for light of wavelength 4800 Å is [given that $(\mu_O - \mu_E) = 0.0058$]

(i) 100 μm

(ii) 30 μm

(iii) 29 μm

(iv) 41 μm

(j) Which of the following relations is correct for a waveguide?

(i) $V_{phase} \times V_{group} = \frac{1}{c^2}$

(ii) $V_{phase} \times V_{group} = c^2$

(iii) $V_{phase} \times V_{group} = c$

(iv) $V_{phase} \times V_{group} = \frac{1}{\sqrt{c}}$

where V_{phase} = phase velocity, V_{group} = group velocity and c = velocity of light

(Continued)

2. Answer the following questions (any *five*) : 2×5=10

(a) **Define intrinsic impedance and state how it is different from wave impedance.**

(b) **Calculate the velocity of e.m. wave in vacuum. Given** $\mu_0 = 4 \times 10^{-7}$ kg m/C^2,

$$\epsilon = \frac{1}{(36\pi \times 10^9)} \frac{C^2 s^2}{kg \cdot m^3}.$$

(c) **Show that the phase velocity in a conducting medium is** $V = \sqrt{\frac{2\omega}{\mu\sigma}}$, **where the symbols have their usual meanings.**

(d) **Starting from the given relation** $f_P = \frac{1}{2\pi}\sqrt{\frac{Ne^2}{m\epsilon_0}}$, **show that the refractive index** $n = \sqrt{1 - \frac{80.6\,N}{f^2}}$, **where the symbols have their usual meanings.**

(e) If in free space $\vec{H} = (10^8 t - kx)\hat{a}y \ \frac{A}{m}$, find k and λ, where k is magnitude of propagation vector.

(f) Write the boundary conditions for electric field intensity ($\vec{E}$) and magnetic field intensity ($\vec{H}$).

(g) State the necessary conditions for obtaining circularly polarized light.

3. Answer the following questions (any *five*) 5×5=25

(a) Show that energy is conserved at the interface separating the two media for normal incidence. State Brewster's law. 3+2=5

(b) Explain the process of production and detection of circularly polarized light.

(c) Show that the electromagnetic waves obey Snell's law, when they suffer refraction at the interface separating two dielectric media.

(d) What do you mean by waveguide mode? Name three possible modes inside a waveguide. Draw the electric field pattern of the first three modes travelling along waveguide. 2+1½+1½=5

(e) Write a short note on numerical aperture.

(f) Write short notes on momentum density and angular momentum density.

(g) Express Lorentz force $\vec{F} = q[\vec{E} + (\vec{v} \times \vec{B})]$ in terms of electromagnetic scalar and vector potentials. Write Lorentz condition for dielectric and conducting media. 3+2=5

(h) Starting from Maxwell's equations, establish the equation of continuity.

(i) Explain the significance of the following in wave propagating through a ionized medium with the help of refractive index :

(i) $\omega > \omega_p$

(ii) $\omega^2 > \omega_p^2$

(iii) $\omega < \omega_p$

where ω_p is plasma frequency and ω is the frequency of the electromagnetic wave. State for which medium $\sigma > \omega\varepsilon$ condition holds good. Write the value of ε for free space. 3+1+1=5

4. Answer the following questions (any *two*) : 10×2=20

(a) Show that for normal incidence of e.m. wave on a metal surface, the reflection coefficient is given by $R = 1 - 2\sqrt{\frac{2\omega\varepsilon_1}{\sigma}}$, where the symbols have their usual meanings. Using this relation, explain why metals are opaque to light. 8+2=10

(b) (i) Write a short note on retardation plate.

(ii) Explain the construction and working of Laurent's half-shade polarimeter. 5+5=10

(c) (i) Derive e.m. wave equation in a conducting medium from Maxwell's electromagnetic field equations.

(ii) Find the magnitude of propagation constant $K = \alpha + j\beta$, at 100 MHz for a medium in which $\varepsilon_r = 10$, $\mu_r = 10$ and $\sigma = 1 \frac{s}{m}$. 5+5=10

(d) (i) Write a short note on gauge transformations.

(ii) What is *V*-number of a waveguide? State the physical significance of *V*-number.

(iii) With a suitable diagram, explain the configuration of a planer dielectric waveguide. 5+(1+2)+2=10

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