U.G. 6th Semester Examination - 2021

PHYSICS

Course Code : BPHSCCHC601

Course Title : Electromagnetic Theory

Full Marks : 30 Time : 2 Hours

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

1. Answer any **ten** questions: 1×10=10

   a) In free space, electric field $\vec{E} = 20\cos(\omega t - 50x)\hat{j}\ v/m$. Calculate the displacement current density, J_D.

   b) Prove that the dimension of Poynting vector is MT^{-3}.

   c) What is the physical significance of the equation $\vec{\nabla} \cdot \vec{B} = 0$?

   d) What do you mean by Coulomb Gauge and Lorentz Gauge?

   e) Write down the boundary conditions for a plane electromagnetic wave incident on a plane boundary between two non-conducting media.

   f) "Light waves can be polarized but sound waves cannot" – Explain.

   g) A right-circularly polarized beam is incident on a calcite half-wave plate. What will be the polarization of the emergent beam?

   h) What do you mean by TE and TM mode for waveguide?

   i) State Malus's law.

   j) What do you mean by specific rotation?

   k) What do you mean by single mode fiber?

   l) For a waveguide, write down the relation between guide wavelength and cut-off wavelength.

   m) What is an evanescent wave?

   n) State the Brewstar's law.

   o) How does refractive index of a dispersive medium vary with frequency?

2. Answer any **five** questions: 2×5=10

   a) Explain how Maxwell modified the Ampere's circuital law.

   b) Write down the Maxwell's inhomogeneous wave equation satisfied by scalar and vector potential.

   c) Prove that electromagnetic wave in isotropic dielectric is transverse in nature.

d) A current distribution gives rise to a magnetic vector potential $\vec{A}(x,y,z) = xy\hat{i} - xyz\hat{j} + y^2z^2\hat{k}$. Find the corresponding magnetic field $\vec{B}$ at (1,1,0).

e) Show that the skin depth in a poor conductor $(\sigma \ll \omega\epsilon)$ is $\left(2/\sigma\right)\sqrt{\epsilon/\mu}$ (the symbols have their usual meanings).

f) An EM wave polarized perpendicular to the plane of incidence, impinges at 30^o on a glass slab having refractive index 1.5. Find the amplitude reflection and transmission coefficient.

g) Find the cut-off frequency for a rectangular waveguide of dimension 7cm×3.5 cm operating in the TE_{10} mode. Also calculate the phase velocity of the wave in the guide at a frequency of 3.5 GHz.

h) Calculate the thickness of a half-wave plate for sodium light (λ = 5893Å), given n_0=1.55 and the ratio of velocity of O component and E component is 1.006. Is the crystal positive or negative?

3. Answer any **two** questions: 5×2=10

a) Mention the two assumptions made in the Lorentz electromagnetic theory of dispersion. When a plane electromagnetic wave is incident on a gaseous medium, prove that its dielectric

constant can be expressed as,

$$K = 1 + \frac{Ne^2}{m\epsilon_0}\sum_j \frac{f_j}{\left(\omega_j^2 - \omega^2\right) - i\gamma_j\omega}$$ (symbols have their usual meanings). 1+4=5

b) Consider the propagation of electromagnetic waves in a rectangular wave guide in TE mode. Show that there is a certain minimum frequency below which no transmission is possible and obtain the expression for that frequency.

Show that the TM_{01} and TM_{10} modes in a rectangular waveguide do not exist. 3+2=5

c) Explain Fresnel's theory of optical rotation. Describe the state of polarization of the wave represented by

$$\vec{E}(z,t) = \hat{i}E_0\cos(kz - \omega t) + \hat{j}E_0\sin(kz - \omega t).$$

3+2=5

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