B. Sc. Physics (Hons.) Examination, 2023

(3rd Year, 2nd Semester)

Electromagnetic Theory

Paper – CORE 13

Time : 2 hours Full Marks : 40

Answer ***any four*** questions. 4×10=40

Symbols used have their usual meanings.

1. a) Discuss about the importance of Maxwell's modification to Ampere's law.

   b) For a monochromatic plane wave traveling in the z direction and linearly polarized in the x direction, find all elements of the Maxwell stress tensor. Discuss whether the obtained result has any physical significance.

   c) Write down the Poynting's theorem. 3+(3+2)+2

2. a) For electromagnetic wave propagation through a conducting medium, show that the magnetic field lags behind the electric field. Is the wave transverse in nature? Explain.

   b) How the skin depth in a good conductor depends on the wavelength of electromagnetic wave? (5+2)+3

3. a) What are s-polarised and p-polarised waves? Write down the boundary conditions of the electric and magnetic field vectors in case of p-polarised waves

and hence establish the Fresnel reflection and transmission coefficients.

b) An unpolarised wave is polarised after reflection if the angle of incidence takes a particular value depending on the medium. Explain this phenomenon using Fresnel coefficients. (2+3+3)+2

4. a) Show that, in case of total internal reflection, the phase change is given by

$$2\phi = 2\tan^{-1}\left[\left(\frac{n_1}{n_2}\right)^2 \frac{\left(\sin^2\theta_i - \sin^2\theta_c\right)^{\frac{1}{2}}}{\cos\theta_i}\right]$$

where $n_1 > n_2$.

b) What are positive and negative crystals? Within an anisotropic crystal, $\vec{E}$ and $\vec{D}$ are not parallel. Establish it mathematically to show that

$$\vec{D} = \frac{n_\omega^2}{c^2\mu_0}\left[\vec{E} - \left(\hat{k}.\vec{E}\right)\hat{k}\right]. \qquad 3+(2+5)$$

5. a) The x and y components of the electric field are given by $E_x = E_0 \sin\left(kz - \omega t + \pi/3\right)$ and $E_y = E_0 \sin\left(kz - \omega t - \pi/6\right)$. Determine the state of polarization and show it in a schematic diagram.

b) Prove that, for a half wave plate, the thickness of the crystal may be given by $d = \left(2m+1\right)\frac{\lambda}{2\left(n_0 - n_e\right)}$.

c) A left circularly polarized light ($\lambda = 5893$ Å) falls on a calcite crystal (with its optic axis lying parallel to the surface) of thickness 0.005141 mm. Show that the emerging beam is right circularly polarised. Given: $n_0 = 1.65836$, $n_e = 1.48641$. 3+4+3

6. a) Prove that TM_{10} mode of electromagnetic wave cannot propagate in a rectangular wave guide. Then find out the lowest cut-off value of frequency for propagation of TM mode. Will the cut-off frequency change if the wave guide is filled with a dielectric medium with dielectric constant $\in_r$?

b) Find the ratio of the lowest TM mode cutoff frequency to the lowest TE mode cutoff frequency, for a given wave guide. (5+1+2)+2