

**B. SC. PHYSICS EXAMINATION, 2022**

( 3rd Year, 2nd Semester )

**SUBJECT : ELECTROMAGNETIC THEORY**

Time : Two hours

Full Marks : 40

Answer any four questions. Symbols used have their usual meanings.

1. (a) A parallel plate capacitor made of two circular disks of radius  $R$  separated by small distance  $d$ , are connected to an external source of alternating emf with voltage  $V(t) = V_0 \sin \omega t$ .  
 (i) Find out the ratio of capacitor charging current ( $i_c$ ) and displacement current ( $i_d$ ) in the circuit.  
 (ii) If a very thin wire of resistance  $P$  is connected between two metal plates along the axis of the capacitor, Find out the expression for magnetic field in the gap between two metal plates of the capacitor.
- (b) What is the physical significance of Poynting vector?  
 (c) The differential form of Poynting's theorem can be written as

$$\frac{\partial u}{\partial t} = -\vec{\nabla} \cdot \vec{S}$$

where  $u$  is the total energy density (mechanical + electromagnetic) of the electromagnetic field and  $\vec{S}$  is the Poynting vector. How this mathematical statement imply the conservation of energy? Explain.

(2 + 3) + 2 + 3

2. (a) Show that an electromagnetic wave propagating in "free space" is transverse in nature.  
 (b) Consider an electromagnetic plane wave is propagating in a conducting medium. Calculate the energy density and intensity of the wave inside the conductor.  
 (c) Is the skin depth a characteristic parameter of conducting medium? Justify your answer.

3 + 5 + 2

3. (a) Write down (proof not needed) the boundary conditions obeyed by different components of  $\vec{E}$  and  $\vec{B}$  at the interface of two dielectrics. Hence prove that the discontinuity of  $\vec{B}$  follows from the discontinuity of the derivative of vector potential  $\vec{A}$ .  
 (b) Draw a clear diagram showing the vectors  $\vec{k}$ ,  $\vec{E}$  and  $\vec{H}$  for incident, reflected and transmitted waves when a p-polarized electromagnetic wave falls obliquely on the interface of two dielectrics.  
 (c) Consider normal incidence from air on water. The refractive index of water is 1.33 for visible light and 9 for radio-frequency waves. Use these information to compare the reflectance in these two cases. What should be the reason behind the fact that the reflectance is higher in case of sea surface?

(2 + 3) + 2 + (2 + 1)

4. (a) Establish Brewster's law and hence explain the case of polarization by reflection.  
 (b) Show that in case of total internal reflection, the angle of refraction is imaginary. Give a schematic plot of reflectance as a function of angle of incidence in case of total internal reflection for both s- and p-polarized waves.  
 (c) What is the dielectric tensor? Show that it is a symmetric tensor.

(2+1)+(2+1)+(2+2)

5. (a) For calcite, the values of  $n_o$  and  $n_e$  are 1.68134 and 1.49694 respectively when  $\lambda = 4046 \text{ \AA}$ . For  $\lambda = 7065 \text{ \AA}$ ,  $n_o$  and  $n_e$  become 1.65207 and 1.48359 respectively. A left circularly polarized beam is incident normally on a calcite quarter wave plate which has the optic axis parallel to the surface. Obtain the state of polarization of the emergent beam.
- (b) Assume that the principal axes of an anisotropic crystal are lying along  $x$ ,  $y$  and  $z$  direction. Consider the incidence of an electromagnetic wave along  $x$ -axis. Show that through the crystal the propagation will be as  $y$ -polarized and  $z$ -polarized waves. 4 + 6
6. (a) For a given rectangular waveguide of dimension  $2.28 \text{ cm} \times 1.01 \text{ cm}$ , what TE mode will propagate if the driving frequency is  $1.70 \times 10^{10} \text{ Hz}$ ?
- (b) Find out the lowest possible TM mode that can propagate in a rectangular waveguide.
- (c) What are the differences between single-mode optical fiber and multi-mode optical fiber?

2 + 5 + 3