Name of the Department	:	Physics
Name of the Course	:	B.Sc. (Hons.) Physics-CBCS_Core
Name of the Paper	:	Electromagnetic Theory
Semester	:	VI
Unique Paper Code	:	32221601
Question paper set number	:	B

Duration: 3 Hours Maximum Marks: 75

Instructions for Candidates

Attempt any **four** questions.
All Questions carry equal marks.

1) **(a)** In a free space $\mathbf{E} = 0.5 \cos(\omega t - \beta x)\ \hat{y}$ V/m. Find the total power passing through a circular plate of area 50 sq cm on the plane $x + y = 5$

(b) Show that Ampere's law fails for non-steady current.

(c) Two plates of area 0.8 sq cm are separated by a distance of 0.3 mm to form a capacitor. The region between the plates is filled with a dielectric having $\varepsilon_r = 5$ and conductivity 0.15 S/m. A signal of amplitude 8V and frequency 20 MHz is applied between the capacitor plates. Find the value of total current flowing between the capacitor terminals.

(d) What is displacement current? List three differences between conduction current and displacement current

(e) Starting from the Maxwell's equations, establish the Coulomb's law of electrostatics.

(3+4+3+5.75+3)

2) **(a)** What is the phase difference between electric and magnetic field vectors in a dielectric medium? Justify your answer.

(b) What is the physical significance of intrinsic impedance? Starting from Maxwell's equations for a dielectric medium, obtain the expression for intrinsic impedance. And compare it with corresponding expression in free space.

(c) The magnetic field of a plane electromagnetic wave in a dielectric medium of $\mu_r = 1$ is given by the following expression.

$$\mathbf{H} = 30 \cos(2\pi \times 10^{-6}\, t + 9x)\ \hat{y}\ \text{mA/m}$$

Find the value of,

(i) ε_r
(ii) Wavelength of the wave
(iii) Polarization of the wave
(iv) Electric field
(v) Sketch the wave at $t = 0$ and $t = t_1$ when the wave has advanced $\lambda/4$

(3+5.75+10)

3) **(a)** An electromagnetic wave is propagating along the z-axis. It gets totally reflected when it is incident from air on a surface having non-zero permeability and permittivity. Show that the superposition of incident and reflected wave results in a standing wave. Determine the time averaged Poynting vector.

(b) Can a medium behave as a conductor at one frequency and dielectric at another frequency? Explain with an example.

(c) Consider a plane electromagnetic wave propagating in a material having conductivity

10 S/m and dielectric constant 8. If the electric field of the wave has amplitude 25 V/m and a frequency of 50 MHz, then,

(i) Calculate phase shift constant, attenuation constant and intrinsic impedance.

(ii) Write the time domain expression of electric and magnetic field if the wave is polarized in y- direction and is propagating in negative z- direction.

(8.75+4+6)

4) **(a)** A plane electromagnetic wave having power density 5 W/m^2 is incident at an air-dielectric plane interface with perpendicular polarization. If the parameters of the dielectric are $\varepsilon_r = 4$ and $\mu_r = 1$ and angle of incidence is 60°, find the power density of the reflected and transmitted waves.

(b) Explain the phenomenon of double refraction.

(c) The electric field of a polarized light is given by the following expression.

$$\mathbf{E} = 20 \cos(\omega t - kz)\ \hat{x} + 35 \sin(\omega t - kz)\ \hat{y}\ \text{V/m}.$$

Determine the state of polarization of this wave. If this wave passes through a quarter wave plate what will be the state of polarization of the emergent wave?

(d) The equation of continuity valid for an open surface or closed surface? Is it dependent on the geometrical shape of the surface? Justify your answer.

(4+6.75+4+4)

5) **(a)** Use the Maxwell's equations to derive the wave equation for the propagation of TE modes of EM wave in a symmetric planar waveguide whose refractive index profile is given by,

$n(x) = n_1$ for $|x| < d/2$ and

n_2 for $|x| > d/2$ where d is the thickness of the film

(b) Obtain the eigen-value equations for symmetric modes and anti-symmetric modes; and thus show that there exists only two TE modes, one symmetric and one anti-symmetric modes, for $\pi < V < 2\pi$.

(c) If a symmetric planar waveguide of thickness 6.8 μm is used to support only a single pair of TE and TM modes at wavelength $\lambda = 1.36$ μm, determine the maximum possible value of n_1 if $n_2 = 1.436$.

(7.75+8+3)

6) **(a)** Show that propagation of electromagnetic waves is possible in ionized medium only if the refractive index is real.

(b) Show that ionosphere behaves like a medium having a refractive index given by,

$$\{1 - (81 n_0/f^2)\}^{0.5}$$

Here, n_0 is the electron number density in m^3 and f is the frequency

(c) Show that the electromagnetic potentials (**A**, ϕ), in a uniform electric and magnetic field can be expressed as, $\mathbf{A} = 1/2\ (\mathbf{B} \times \mathbf{r})$ and $\phi = -\mathbf{E} \cdot \mathbf{r}$

(7.75+5+6)