Quiz-2: Radio Frequency-Based Sensors Design: Principles and Applications

NOTE: No query is allowed during the exam. Write your assumptions (if any) for each question.

Time allotted: 1 hr **[MM=45]**

Q1 (i) Define the terms- **[4×2=8]**

(a) Stimulus, (b) Sensor, (c) Actuator, and (d) Transducer with definition and examples.?

Q2 A vector field **F** is given as $\mathbf{F} = xy\mathbf{a}_x + y^2\mathbf{a}_y + xz\mathbf{a}_z$. Find **[3×2=6]**

(c) Find $\nabla \cdot \mathbf{F}$ (divergence of F).

(d) Find $\nabla \times \mathbf{F}$ (curl of F).

(e) Find whether **F** is solenoidal or rotational

Q3 An electromagnetic wave is propagating in the positive x-direction through a vacuum and is described by the electric field equation: **[5×2=10]**

$$\vec{E}(x,t) = E_0 \sin(kx - \omega t + \phi)\,\hat{j}$$

Given:

- Electric field amplitude (E_0) = 500 V/m
- Frequency (f) =6×10^{14} Hz
- Phase constant (Φ) = $\pi/4$, radians.
- The speed of light c = 3×10^8 m/s.
- Π =3.14159

Calculate

1. Angular frequency (ω)
2. Wavelength (λ)
3. Wave number (K)
4. Phase velocity
5. Write the magnetic field equation, including direction.

Q4. Attempted Any 2 questions. **[5×3=15]**

(a) Explain the concept of (a) wave impedance and (b) Poynting Vector in an electromagnetic wave and derive its value for free space.

(b): Explain the Energy density of the EM wave and prove that the energy density associated with the electric field is equal to that of the magnetic field in a vacuum.

(c). Write down Maxwell's Equations in a Dielectric Medium: also derive the wave equation for electric and magnetic fields.

(d) Starting from the integral form of Ampère's law with Maxwell's correction, derive its differential form. Highlight the role of the displacement current in this conversion.

Q5. Which is the correct option? **[6×1=6]**

(i) Radio waves typically have frequencies in the range of:

A) $30\ \text{Hz} - 300\ \text{GHz}$
B) $10^9\ \text{Hz} - 10^{12}\ \text{Hz}$
C) $3 \times 10^{14}\ \text{Hz} - 7 \times 10^{14}\ \text{Hz}$
D) $10^{18}\ \text{Hz} - 10^{20}\ \text{Hz}$

(ii) Which represents the correct conversion from Cartesian coordinates (x, y) to polar coordinates (r, θ)?

A) $r = \sqrt{x^2 + y^2}, \theta = \tan^{-1}(\frac{y}{x})$
B) $r = x + y, \theta = x - y$
C) $r = x^2 + y^2, \theta = \frac{x}{y}$
D) $r = \sqrt{x^2 - y^2}, \theta = \tan(\frac{y}{x})$

(iii)Which of the following represents the correct conversion from Cartesian coordinates (x, y, z) to spherical coordinates (r, θ, φ)?

A) $r = \sqrt{x^2 + y^2 + z^2}, \theta = \tan^{-1}(\frac{y}{x}), \phi = \cos^{-1}(\frac{z}{r})$
B) $r = x + y + z, \theta = \tan^{-1}(\frac{x}{y}), \phi = \sin^{-1}(\frac{z}{r})$
C) $r = \sqrt{x^2 + y^2}, \theta = \sin^{-1}(\frac{z}{x}), \phi = \tan^{-1}(\frac{y}{x})$
D) $r = x^2 + y^2 + z^2, \theta = \tan(\frac{y}{x}), \phi = \cos^{-1}(\frac{r}{z})$

(iv) Two electromagnetic waves have intensities in the ratio of 4:1. What is the ratio of their electric field amplitudes?

A) 4:1

B) 2:1

C) 1:2

D) 1:4

(V) Which statement correctly describes the physical significance of bound and free charges in a dielectric material?

A) Bound charges are associated with the alignment of molecular dipoles, while free charges move freely in a conductor.

B) Bound charges can move throughout the dielectric, while free charges are fixed within atoms.

C) Bound charges exist only on the surface of a dielectric, while free charges are uniformly distributed.

D) Bound charges produce a uniform electric field, while free charges produce a non-uniform electric fiel

(VI) What happens to the frequency of light when it travels from air to glass?

A) Increases

B) Decreases

C) Remains constant

D) Becomes infinite.

END.

Attach the question paper with your exam sheet."

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