Student Matriculation No:

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EEG 712: Electromagnetic Theory Assignment

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EEG 712 Electromagnetic Theory

Problem 1

a. For a particular electromagnetic field, the Cartesian component of the electric field vector are given as:

$$E_x = E_y = 0 \qquad E_z = E_0 \cos(\alpha x)\cos(\omega t)$$

Given that the magnetic field strength at time $t = 0$ is $\overline{H} = 0$, show that

$$H_x = H_z = 0 \qquad H_y = H_0 \sin(\alpha x)\sin(\omega t)$$

1. Determine H_0 in terms of E_0 and the permeability μ of the medium in which the field exists.

b. The Cartesian (x,y,z) components of the electric vector of a particular wave field propagating in an ideal dielectric medium of permeability μ_0 and permittivity ε are

$$E_x = 0; \qquad E_y = E_0 \sin(\omega t - \alpha x); \qquad E_z = E_0 \cos(\omega t - \alpha x)$$

Where E_0, ω, α are constants.

1. What is the state of polarization of this wave field?
2. Obtain expressions for the Cartesian component of the magnetic field strength, $\overline{H}$.
3. Show that the Poynting vector for the wave is independent of time and the spatial co-ordinates

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Problem 2

a. Let $\rho_v = 5e^{-0.1\rho}(\pi - |\phi|)\frac{1}{z^2+10}$ $\mu\text{C/m}^3$ in the region $0 \le \rho \le 10$, $-\pi < \phi < \pi$, all z, and $\rho_v = 0$ elsewhere. Determine the total charge present

Calculate the charge within the region $0 \le \rho \le 4$, $-\frac{1}{2}\pi < \phi < \frac{1}{2}\pi$, $-10 < z < 10$.

b. A spherical volume having a $2\ \mu\text{m}$ radius contains a uniform volume charge density of $10^{15}\ \text{C/m}^3$. (a) What total charge is enclosed in the spherical volume? (b) Now assume that a large region contains one of these little spheres at every corner of a cubical grid 3mm on a side, and that there is no charge between the spheres. What is the average volume charge density throughout this large region?

Problem 3

a. A certain nonmagnetic material has the material constants $\varepsilon_R^{'} = 2$ and $\varepsilon''/\varepsilon' = 4\times10^{-4}$ at $\omega = 1.5\ \text{Grad/s}$. Find the distance a uniform plane wave can propagate through the material before: (a) it is attenuated by 1 Np; (b) the power level is reduced by one-half; (c) the phase shift of 360 degs.

b. Let $\eta = 250 + j30\Omega$ and $jk = 0.2 + j2\ \text{m}^{-1}$ for a uniform plane wave propagating in the a_z direction in a dielectric having some finite conductivity. If $|E_s| = 400\ \text{V/m}$ at $z = 0$, find: (a) $P_{z,av}$ at $z = 0$ and $z = 60\ \text{cm}$; (b) the average ohmic power dissipation in watts per cubic meter at $z = 60\ \text{cm}$

Problem 4

a. A wireless communication network installed in the PG lecture room is allowed to use a $10\ \text{V/m}$ radiation at 2.45 GHz.

   1. Find the power density in students, who are likely to use the room, if the wave is incident normally,
   2. Find the depth over which the field decreases by $1/e$.

Assume that the student's body can be modeled as a semi-infinite plane medium with $\varepsilon_r = 47$ and $\sigma = 2.21\ \text{S/m}$ and that the radiation is in the form of a uniform plane wave.

   3. How do these results compare if the radiation frequency decreases to 40 MHz ($\varepsilon_r = 97$ and $\sigma = 0.7\ \text{S/m}$) at this frequency?

b. The Department decides to establish a wireless network in the PG lecture room using a 5.6 GHz signal. At the same time, the Department decides to re-furnish the furniture in the PG lecture room and these are to made from wooden boards from Iroko wood ($\varepsilon_r = 2.1$).

   1. Find the appropriate thickness of the boards that keeps the furniture (assume partitions) from affecting the signal strength. Assume that the network uses uniform plane waves.

Problem 5

a) An infinite filament on the z axis carries $20\pi\ \text{mA}$ in the a_z direction. Three uniform cylindrical current sheets are also presents: $400\ \text{mA/m}$ at $\rho = 1\ \text{cm}$, $-250\ \text{mA/m}$ at $\rho = 2\ \text{cm}$, and $-300\ \text{mA/m}$ at $\rho = 3\ \text{cm}$. Calculate H_ϕ at $\rho = 0.5,\ 1.5, 2.5, \text{and } 3.5\ \text{cm}$.

An airplane communicates with a submerged submarine using a uniform plane wave of 100 MHz. The wave propagating along the $+z$ (downward) in air is incident normally on the seawater (interface at $z=0$) with a power density of $20\ \mathrm{W/m^2}$. Find the electric and magnetic fields in the seawater. If the submarine requires at least $1\ \mu\mathrm{W/m^2}$ for a reliable communication, find the depth up to which it can be go without losing the signal. Assume $\varepsilon_r = 80$ and $\sigma = 4.5\ \mathrm{S/m}$ for the seawaer