Reading

Textbook: *Elements of Electromagnetics*, 7th Ed.
Matthew N. O. Sadiku
Oxford University Press

Assignment: Read Chapter 10.

Lectures: Topic 7
From *Electromagnetic Field Theory*
https://empossible.net/academics/emp3302/

Wave Parameters

An electromagnetic plane wave with angular frequency $\omega = 1.5080 \times 10^{10}\ s^{-1}$ has the following electric and magnetic field components.

$$\begin{aligned}\vec{E}(\vec{r}) &= (-7.5748 - j8.7371)\exp(-j22.2932x + j44.5864y - j66.8796z)\hat{a}_x \\ &+ (6.3788 - j7.8847)\exp(-j22.2932x + j44.5864y - j66.8796z)\hat{a}_y \ \text{V/m} \\ &+ (6.7774 - j2.3441)\exp(-j22.2932x + j44.5864y - j66.8796z)\hat{a}_z \\ \vec{H}(\vec{r}) &= (-0.0350 + j0.0303)\exp(-j22.2932x + j44.5864y - j66.8796z)\hat{a}_x \\ &+ (-0.0316 - j0.0255)\exp(-j22.2932x + j44.5864y - j66.8796z)\hat{a}_y \ \text{A/m} \\ &+ (-0.0094 - j0.0271)\exp(-j22.2932x + j44.5864y - j66.8796z)\hat{a}_z\end{aligned}$$

Problem #1 – Polarization Vector $\vec{P}$

Determine, simplify, and write the expression for the polarization vector $\vec{P}$ of this wave.

Problem #2 – Frequency f

Determine the angular frequency ω and ordinary frequency f of this wave.

Problem #3 – Wave Vector $\vec{k}$

Write the expression for the wave vector $\vec{k}$ of this wave.

Problem #4 – Polarization Type

Write the expression for the polarization vector $\vec{P}$ of this wave. Determine the polarization of this wave as linear polarization (LP), right circular polarization (RCP), left circular polarization (LCP) or elliptical polarization (EP). Justify your answer.

Problem #5 – Wavelength λ

Calculate the wavelength λ and the free space wavelength λ_0 of the wave.

Problem #6 – Refractive Index n & Impedance η

Calculate the refractive index n and the impedance η of the medium.

Problem #7 – Relative Permittivity ε_{r} and Relative Permeability μ_{r}

Calculate the relative permittivity ε_{r} and relative permeability μ_{r} of the medium.

Problem #8 – Poynting Vector $\vec{\wp}$

Calculate the RMS Poynting vector $\vec{\wp}$ of the wave. Calculate the angle between the RMS Poynting vector $\vec{\wp}$ and the wave vector $\vec{k}$.

Material Properties of Waves

Problem #9 – Complex Permittivity

At 5.6 GHz, A lossy ceramic material has a real-valued dielectric constant $\varepsilon_{\mathrm{r}} = 3.5$ and a conductivity of $\sigma = 80\ \mathrm{S/m}$. Calculate the complex relative permittivity $\tilde{\varepsilon}_{\mathrm{r}}$ that describes this material.

Problem #10 – Loss Tangent

Calculate the loss tangent $\tan\delta$ of the material described in Problem #9.

Problem #11 – Skin Depth

Calculate the skin depth d of the material described in Problem #9.

Dispersion Relation

Problem #12 – Derive the Dispersion Relation

The wave equation $\nabla^2\vec{E} - (k_0 n)^2\vec{E} = 0$ inside of a linear, homogeneous, and isotropic (LHI) medium has a solution of $\vec{E} = \vec{E}_0 \exp\left(-j\vec{k}\cdot\vec{r}\right)$. Given this solution, derive the dispersion relation for this medium.

Problem #13 – Apply the Dispersion Relation

A certain LHI medium has relative permeability $\mu_{\mathrm{r}} = 1.2$ and relative permittivity $\varepsilon_{\mathrm{r}} = 9.5$. A wave is propagating through this medium with wave vector components $k_x = 353.8\ \mathrm{m}^{-1}$ and $k_y = 612.8\ \mathrm{m}^{-1}$. Calculate the missing wave vector component k_z for a wave with frequency 20 GHz.