THE UNIVERSITY OF TEXAS AT DALLAS

Electromagnetic Engineering I

EE 4301

Spring 2008
Assignment 7

Due Date and Time:

At the beginning of class, February 25, 2008

Reading:

N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Chapter 5

Problems:

Please write your answers to the following problems on engineering paper. No credit will be given for work handed in on other types of paper.

1. A uniform plane wave with frequency $f = 3$ GHz is propagating in a material characterized by $\epsilon_r = 9.0$, $\mu_r = 1$, and $\sigma = 0$. Given the foregoing data and the magnetic field intensity

$$\mathbf{H}(\mathbf{r}, t) = 10\,\cos(\omega t - kz)\,\hat{\mathbf{x}} \qquad \mathrm{A/m}, \tag{1}$$

   determine

   (a) the velocity of propagation of electromagnetic waves,

   (b) the value of ω in Eq. (1),

   (c) the wavelength,

   (d) the value of k, and

   (e) the magnitude, direction and units of the electric field intensity that corresponds to the magnetic field intensity in Eq. (1).

2. Write down equations for the electric and magnetic field intensities of a plane wave that is propagating in the direction (1, 1, 0), given that the peak magnitude of the electric field is 10 V/m, the electric field vector is parallel to the Z axis, and the frequency is $f = 3$ GHz. Assume that $\epsilon_r = 1$, $\mu_r = 1$, and $\sigma = 0$.

3. Find the EMF induced in a square coil of 1 turn with an area of $(1.0\ \mathrm{cm})^2$ that is placed in a plane that is perpendicular to the **H** field

$$\mathbf{H} = -\frac{1}{4\pi \times 10^7 \mu_0} \cos(4\pi \times 10^{10} t - 2\pi \times 100\, z)\, \hat{\mathbf{x}} \qquad \mathrm{A/m} \tag{2}$$

Assume that the field and the coil are in vacuum, and please remember to use correct units!

4. A long solenoid is wound with 30 turns of wire per centimeter, and can carry a current of 0.5 A. What is the magnetic field strength inside the solenoid? (Please remember to use correct units!)

5. Find the value of k (in radians/m) such that the fields

$$\begin{aligned} &\mathbf{E} = 20\cos(2\pi \times 10^{10} t - kz)\, \hat{\mathbf{y}} \qquad \mathrm{V/m} \\ \text{and} \quad &\mathbf{H} = -\frac{20k}{2\pi \times 10^{10} \mu_0} \cos(2\pi \times 10^{10} t - kz)\, \hat{\mathbf{x}} \qquad \mathrm{A/m} \end{aligned} \tag{3}$$

satisfy Maxwell's equations in free space (vacuum).

6. Is the following vector field a possible magnetic flux density, **B**? (Support your answer.)

$$\mathbf{B} = x\hat{\mathbf{x}} + y\hat{\mathbf{y}} + z\hat{\mathbf{z}} \ \ \mathrm{T} \tag{4}$$

7. You are given the information that a magnetic field is

$$\mathbf{H} = \hat{\mathbf{y}} \cos(12\pi \times 10^9 t - kz) \qquad \mathrm{A/m} \tag{5}$$

and that $\mu = \mu_0$, $\epsilon = 4\epsilon_0$.

   (a) What is the frequency in Hz?
   (b) What is the propagation velocity of the wave?
   (c) What is the wavelength λ?
   (d) What is the value of the spatial frequency (propagation constant) k?
   (e) What is the electric field **E**?
   (f) What is the Poynting vector $\mathbf{S} = \mathbf{E} \times \mathbf{H}$, given Eq. (5) and your result for the electric field?

8. Write the differential form and the integral form of the Maxwell equation that describes each of the following phenomena:

   (a) There are no magnetic charges.
   (b) The total electric flux through a closed surface is equal to the charge enclosed.
   (c) A time-varying magnetic flux induces an electromotive force.
   (d) A conduction current density and a displacement current density induce a magnetic field.

9. A capacitor filled with a dielectric such that $\epsilon = \epsilon_0$ has an area $A = 9 \times 10^{-4}$ m^2. The electric flux density in the capacitor is approximately

$$\mathbf{D} = \hat{\mathbf{z}} 1.77 \times 10^{-5} \cos(2\pi \times 10^7 t) \qquad \mathrm{C/m^2}. \tag{6}$$

   (a) What is the electric field **E** in the capacitor?
   (b) What is the displacement current density $\partial \mathbf{D}/\partial t$?
   (c) What is the total current through the capacitor?
   (d) Explain, using pictures, words and equations, why **H** cannot be zero inside the capacitor.

10. Check to see which, if either, of the following could be a field that is consistent with Maxwell's equations, assuming that no sources are present ($\rho = 0$, $\mathbf{J} = \mathbf{0}$):

    (a) $\mathbf{E} = \hat{\mathbf{z}}\, xt$ (Cartesian coordinates).

    (b) $\mathbf{B} = \hat{\mathbf{r}}\, \dfrac{C}{r}$ (spherical polar coordinates).

11. You are the engineer in charge of testing a sheet of glass coated with indium-tin oxide to be used in manufacturing liquid-crystal displays. Using the four-electrode method discussed in lecture, you measure the resistance between ring electrodes with radii $a = 1$ cm and $b = 2.72$ cm to be 16 Ω. What is the surface resistance R_s, in Ω/square?