

# THE UNIVERSITY OF TEXAS AT DALLAS



## Electromagnetic Engineering I

### EE 4301

### Spring 2008 Assignment 8

#### Due Date and Time:

At the beginning of class, March 3, 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.

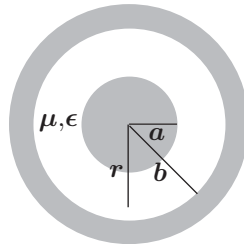
1. This problem pertains to a uniform plane wave with frequency  $f = 1.0$  GHz that is propagating in the direction  $\langle 1, 1, -1 \rangle$  in a material characterized by relative permittivity  $\epsilon_r = 3.0$ , relative permeability  $\mu_r = 1$ , and conductivity  $\sigma = 0$ . Given the foregoing data, the magnetic field intensity

$$\mathbf{H}(x, y, z, t) = (\sqrt{3}/\pi) \cos(\omega t - \mathbf{k} \cdot \mathbf{r}) (\hat{\mathbf{y}} + \hat{\mathbf{z}}) \quad \text{A/m}, \quad (1)$$

and the information that the volume charge density  $\rho = 0$ , find

- (a) the velocity of propagation of electromagnetic waves,  $v$ ,
  - (b) the value of the wave impedance,  $\eta$  (leave  $\eta$  in terms of  $\pi$ , please),
  - (c) the value of  $\omega$  in Eq. (1) (leave  $\omega$  in terms of  $\pi$ , please),
  - (d) the magnitude, direction and units of the vector  $\mathbf{k}$  in Eq. (1),
  - (e) and the magnitude, direction and units of the electric field intensity that corresponds to the magnetic field intensity in Eq. (1).
2. If a time-dependent magnetic flux density is  $\mathbf{B}(x, y, z) = 2 \cos(2\pi \times 10^4 t) \hat{\mathbf{z}}$  T, find the electromotive force around a circular loop in the  $XY$  plane if the loop area is  $10^{-4}$  m<sup>2</sup>.

- Find the magnetic field intensity  $\mathbf{H}$  inside a solenoid that has 30 turns/cm and carries a current of  $\frac{1}{3}$  A. The axis of the solenoid is parallel to  $\hat{\mathbf{z}}$ , and the direction of current flow in the windings is in the direction of the fingers of your right hand if your right thumb points along  $\hat{\mathbf{z}}$ .
- Find the curl of the vector field  $\mathbf{A}(r, \phi, z) = \hat{\phi}$ , where  $\hat{\phi}$  is the unit vector in the  $\phi$  direction in *cylindrical* coordinates.
- The figure below shows a cross section of a coaxial cable. The inner conductor carries a current of 1 A directed out of the paper, and has a positive surface charge density of  $1 \text{ C/m}^2$ . The inner radius is  $a = 1 \text{ mm}$ , and the outer radius is  $b = 4 \text{ mm}$ . Sketch at least 5 lines of  $\mathbf{E}$  and 3 lines of  $\mathbf{H}$ , distinguishing carefully which features are lines of  $\mathbf{E}$  and which features are lines of  $\mathbf{H}$ . Please show the directions of the field lines.



- An electromagnetic plane wave with a magnetic field

$$\mathbf{H}(x, y, z, t) = 16 \cos(\omega t - kz) \hat{\mathbf{y}} \quad \text{A/m} \quad (2)$$

is propagating between two metal plates that are parallel to the  $YZ$  plane. The plates intersect the  $X$  axis at  $x = 0$  and  $x = 0.1 \text{ m}$ , respectively. Find the magnitude and direction of the surface current density on the upper plate.

- A conducting sheet oriented parallel to the  $XZ$  plane carries a time-independent *surface* current density  $\mathbf{J}_s = 10 \hat{\mathbf{z}} \text{ A/m}$ . Find the magnitude and direction of the electric field intensity, assuming that the surface resistance is  $2 \Omega$ . Please use correct units.
- The wave impedance of a particular dielectric medium is equal to  $20 \Omega$ . If the electric field of an electromagnetic wave is equal to  $\mathbf{E}(x, y, z, t) = \hat{\mathbf{y}} 10 \cos(2\pi \times 10^9 t - kz)$ , where  $k > 0$ , find the time-averaged power delivered across an area in the  $XY$  plane equal to  $2.0 \text{ m}^2$ .