Midterm #1 of EE101B

Winter, 2014
(Closed Book, 1 Hr)

Name : ________________

UID : ________________

Problem #1. (10 points) Please answer following questions.

(1) [5 points] The left block below shows WRONG four Maxwell's equations. Please correct them and rewrite CORRECT four Maxwell's equations on the right block.

WRONG Maxwell's Eqs.	CORRECT Maxwell's Eqs.
$\nabla \cdot \vec{E} = \rho$	$\nabla \cdot \vec{D} = \rho_v$
$\nabla \cdot \vec{H} = \rho$	$\nabla \cdot \vec{B} = 0$
$\nabla \times \vec{B} = \frac{\partial \vec{E}}{\partial t} + \vec{J}$	$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{J}$
$\nabla \times \vec{E} = \frac{\partial \vec{B}}{\partial t}$	$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$

(2) [5 points] Briefly describe the physical meaning of the intrinsic impedance η in a uniform plane electromagnetic wave. What is its unit?

The intrinsic impedance η in a uniform plane EM wave is defined as the ratio of electric field to magnetic field.

$$\eta = \frac{E}{H}$$

The unit of η is ohm (Ω).

Problem #2. [20 points] The electric field of an electromagnetic wave propagating in a medium is given by

$$\vec{E}(x,y,z,t)=\hat{x}\cdot 4\cos\left(2\pi\cdot 3\times 10^{6}t-\frac{2\pi}{50}z\right)\ [\frac{V}{m}],$$

where t is time in second and z is in meter. Please answer following questions. Make sure to write units if they are required.

(1) [2 points] Is this medium lossless or lossy?

Lossless.

(2) [2 points] What is the propagating direction of this wave?

$+z$

(3) [2 points] Is this wave linearly polarized or circularly polarized or elliptically polarized?

Linearly polarized

(4) [2 points] What is the frequency, f?

3×10^{6} Hz or 3 MHz

(5) [2 points] What is the wavelength, λ inside the medium?

$$\lambda = \frac{2\pi}{k} = 50 \text{ m}$$

(6) [2 points] What is the phase velocity, v_p?

$$v_p = \frac{\omega}{k} = \frac{2\pi\cdot 3\times 10^{6}}{2\pi/50} = 1.5\times 10^{8} \text{ m/s}$$

(7) [2 points] Suppose this medium is nonmagnetic (relative permeability $\mu_r = 1$), what is the relative permittivity ε_r (also called dielectric constant)? We can use he following equation: $k = \beta = \omega\sqrt{\mu\varepsilon} = \frac{\omega}{v_p}$.

$$\frac{v_p}{c} = \frac{1}{\sqrt{\epsilon_r}} \Rightarrow \epsilon_r = 4$$

(8) [2 points] Find the associated magnetic field $\vec{H}(x,y,z,t)$. Assume that the intrinsic impedance is η.

$$\vec{H}(x,y,z,t) = \frac{1}{\eta}\hat{k}\times\vec{E}$$

$$= \frac{1}{\eta_0/\sqrt{\epsilon_r}}\hat{z}\times\vec{E}$$

$$= \frac{1}{60\pi}\hat{y}\,4\cos(2\pi\cdot 3\times10^6 t - \frac{2\pi}{50}z)\ \left(\frac{A}{m}\right)$$

(9) [2 points] What is the phasor form $\vec{E}(x,y,z)$ of this electric field?

$$\vec{E}(x,y,z) = \hat{x}\,4e^{-\frac{2\pi}{50}z} \quad (V/m)$$

(10) [2 points] Suppose a 1 m^2 surface area on the x-y plane. What is the time-averaged power flow over this area? Assume that the intrinsic impedance is η.

$$\vec{S} = \vec{E}\times\vec{H}^* \qquad \eta = 60\pi\ \Omega$$

$$\vec{S} = \hat{z}\frac{4^2}{60\pi} \quad (W/m^2)$$

$$P_{av} = \frac{1}{2}|\vec{S}\cdot\vec{A}| = \frac{1}{2}\times\frac{4^2}{60\pi} = \frac{16}{120\pi}\ W = 42.4\ mW$$

or $$\vec{S} = \hat{z}\frac{|\vec{E}|^2}{2\eta} = \hat{z}\frac{8}{\eta}\ (W/m^2)$$

$$P = \frac{8}{\eta}\ (W)$$