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| October, 2004 Duration: 50 minutes | EE351 Midterm Exam. # 1 (Closed notes & book) | Fall 2004 School of EECS/ WSU |
| Name: _____ | | ID #: _____ |

- Answer all questions?
- Closed books
- Closed notes except for equation sheet.
- No crib notes
- No headphones, cell phones, or pagers.
- No hats
- No guests or visitors during exam.
- See attached equation sheets.

Signature: _____

Problem 1: (28 points)

The magnetic field intensity of a plane wave of angular frequency $\omega = 10^5$ rad/sec is given in phasor form as:

$$\mathbf{H}_s = 0.1 e^{0.1y} e^{j2y} \mathbf{a}_x \text{ A/m}$$

(a) The wavelength is : $\beta = 2, \lambda = 2\pi/\beta = \pi$ meters

(b) The phase velocity is: $u = \omega/\beta = 10^5/2 = 5 \times 10^4$ m/s

(c) The direction of propagation is: $-\mathbf{a}_y$

(d) The direction of the electric field intensity vector for this field is: $-\mathbf{a}_z$

(e) The expression of the actual magnetic field intensity is:

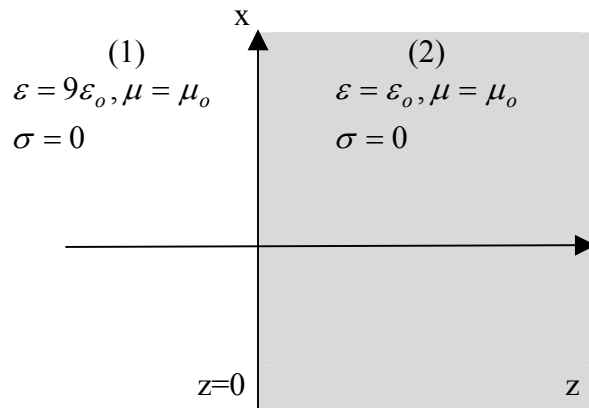
$$\mathbf{H}(y,t) = 0.1 e^{0.1y} \cos(\omega t + 2y) \mathbf{a}_x \text{ A/m}$$

(f) The amplitude of the magnetic field after propagating a distance 100 meters into the medium would be :

_____ e^{-10} _____ times its initial amplitude.

Problem 2: (24 points)

A perpendiculary polarized plane wave is incident on a boundary between two materials with parameters given in the figure below:



a) If $\theta_1 = 15^\circ$, the angle $\theta_2 = \underline{75^\circ}$

b) If $\theta_1 = 15^\circ$, the angle $\theta_3 = \underline{51^\circ}$

$n_1 \sin \theta_1 = n_2 \sin \theta_3$ and $n_1 = c/u = 3$, $n_2 = 1$

c) If the reflected field is zero, the angle $\theta_1 = \underline{45^\circ}$

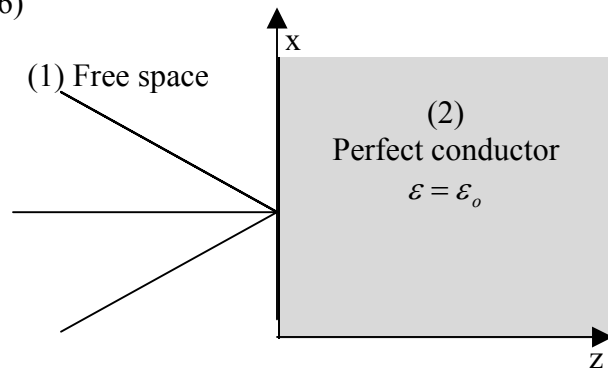
$E_r = \Gamma_T E_i$, $\Gamma_T = 0$, $\theta_1 = \theta_{BT}$

$\tan \theta_{BT} = \sqrt{\frac{\mu_2}{\mu_1}} = 1$,

d) If $\theta_1 = 0$, determine the ratio of the amplitude of the reflected electric field intensity to the amplitude of the incident electric field intensity.

$$\frac{E_r}{E_i} = \Gamma, \quad \Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = \frac{120\pi - 40\pi}{120\pi + 40\pi} = 0.5$$

Problem 3: (16)



A plane wave in air has:

$$\vec{E}_i = 100\mathbf{a}_y \sin(\omega t - x - \sqrt{3}z)$$

is incident on a perfect conductor slab in region $z > 0$. Determine the following:

(a) Propagation vector of the incident \vec{E}_i field? Show \vec{E}_i on the above plot? (4)

$$1. \quad \mathbf{k}_i = \mathbf{a}_x + \mathbf{a}_z\sqrt{3}$$

(b) Propagation constant of the reflected \vec{E}_r field? Sketch on the above plot? (4)

$$\mathbf{k}_r = \mathbf{a}_x - \mathbf{a}_z\sqrt{3}$$

(c) Angle of reflection? (4) $\tan \theta_r = k_x / k_y = 1/\sqrt{3}$

$$\theta_r = 30^\circ$$

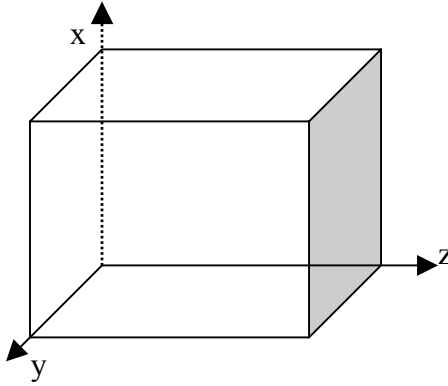
(d) Transmitted Electric field \vec{E}_t ? (2)

$$\text{Medium 2 is perfect conductor, } \vec{E}_t = 0$$

(e) Reflection coefficient Γ at interface $z=0$? (2)

$$\eta_2 = 0, \quad \Gamma = -1.$$

Problem 4: (20)



The above waveguide has perfect conducting metal walls and extends to ∞ in the z-direction. It has dimensions $a = 8$ cm and $b = 6$ cm (a along x-axis) and is filled with lossless dielectric ($\mu = \mu_0$ and $\epsilon = 9\epsilon_0$). One of the TE mode has the following component:

$$E_{ys} = \frac{j\omega\mu}{h^2} \left(\frac{2\pi}{a} \right) H_0 \sin\left(\frac{2\pi x}{a} \right) \cos\left(\frac{3\pi y}{b} \right) e^{-\gamma z}$$

Determine the following:

a) The TE mode of operation (m,n) is ? (4)

$$m=2, n=3$$

b) The phase velocity u' in the unbounded dielectric medium is: (4)

$$u' = 1/\sqrt{\mu\epsilon} = 1/\sqrt{9\mu_0\epsilon_0} = 10^8 \text{ m/s}$$

c) The cut off frequency for this mode is: (4) $f_c = 2.8$ GHz

d) The group velocity for a 5 GHz signal? (5)

$$U_g = 10^8 \sqrt{1 - (2.8/5)^2} \text{ m/s}$$

e) The electric field vector \vec{E} for the TE₁₀ mode? (5)

$$E_{xs} = 0, E_{zs} = 0, \vec{E} = \mathbf{a}_y E_{ys}$$

$$E_{ys} = \frac{j\omega\mu}{h^2} \left(\frac{\pi}{a} \right) H_0 \sin\left(\frac{2\pi x}{a} \right) e^{-\gamma z}$$

Problem 5: (12)

In an air filled wave guide the TE_{10} mode has cutoff frequency $f_c = 12$ GHz. The TE_{01} mode has $f_c = 5$ GHz.

a) The dimensions of the guide are:

$$a = \underline{\quad 1.25 \text{ cm} \quad} \quad \text{and } b = \underline{\quad 3 \text{ cm} \quad}$$

b) The cutoff frequency for the TM_{20} mode when the waveguide is filled with a medium :
 $\mu = \mu_0$, $\epsilon = 4\epsilon_0$

TM_{20} mode is not supported. Cut frequency has no meaning