October 21, 2005 Duration: 50 minutes	EE351 Midterm Exam. # 2 (Closed notes & book)	Fall 2005 School of EECS/ WSU
Name:----------Master solution----------		ID #: ----------

- Answer all questions
- Closed books
- Closed notes (two pages of equations allowed)
- No crib notes
- No headphons, cell phones, or pagers.
- No hats
- No guests or vistors during exam.
- See attached equation sheets.

Signature:_____

	Possible Points	Grade point
1	25	
2	25	
3	25	
4	25	
	100	

Problem 1:
A rectangular copper waveguide filled with a dielectric ($\varepsilon = 4\ \varepsilon_o$) has dimensions a = 1.5 cm, and b= 1 cm. Determine the following for the TE_{10} mode at 10 GHz.

a) medium velocity u' (3):

$$u' = \frac{1}{\sqrt{4\mu_o\varepsilon_o}} = \frac{c}{2} = 1.5x10^8\, m/s$$

b) β_{10} (5):

$$f_{c10} = \frac{u'}{2a} = 5GHz$$

$$\beta' = \frac{\omega}{u'} = \frac{2\pi x10x10^9}{1.5x10^8} = 418.9m^{-1}$$

$$\beta_{10} = \beta'\sqrt{1-(f_c/f)^2} = 362.8$$

c) λ_{10} (4)

$$\lambda_{10} = \frac{2\pi}{\beta_{10}} = 0.0173m$$

d) η_{10} (4):

$$\eta' = \sqrt{\frac{\mu_o}{4\varepsilon_o}} = 377/2 = 188.5\Omega$$

$$\eta_{10} = \frac{\eta'}{\sqrt{1-(f_c/f)^2}} = 211.3\Omega$$

e) Phase velocity u_p (5)

$$u_p = \frac{u'}{\sqrt{1-(f_c/f)^2}} = 1.732x10^8\, m/s$$

f) What is the value of λ_{10} if the frequency is changed to 4 GHz? (4)

Frequency f = 4 GHz is less than cut-off frequency. No propagation. No λ is defined.

Problem 2:

A 5.0 cm by 3.0 cm rectangular waveguide is filled with a dielectric material ($\mu = \mu_o$, $\varepsilon = 4\varepsilon_o$, $\sigma_d = 0$). Given:

$$E_z = 2 \sin(\frac{\pi x}{a}) \sin(\frac{3\pi y}{b}) \cos(\pi 10^{11} t - \beta z) \text{ A/m}$$

Determine the following:

(a) Mode of operation :

TM_{13} mode

(b) Cutoff frequency:

$$u' = \frac{1}{\sqrt{4\mu_o \varepsilon_o}} = \frac{c}{2} = 1.5x10^8 m/s$$

$$f_c = \frac{u'}{2}\sqrt{\frac{1}{a^2} + \left(\frac{3}{b}\right)^2} = 7.65GHz$$

(c) Propagation constant β

$$f_{c13} = 7.65GHz$$

$$\beta' = \frac{\omega}{u'} = \frac{2\pi x 50x10^9}{1.5x10^8} = 2094.7418.9m^{-1}$$

$$\beta = \beta'\sqrt{1-(f_c/f)^2} = 2070m^{-1}$$

(d) The group velocity for the (m = 1, n = 0) mode

TM_{10} is not supported. Group velocity has no meaning

Problem 3:

Circle the correct answer(s): (show all calculations if needed)

(1) The dominant mode for a rectangular waveguide is: (4)

(a) TE_{11} (b) TM_{11} (c) TE_{101} (d) TE_{10}

(2) The TM_{10} mode can exist in a rectangular waveguide. (4)

(a) True (b) False

(3) For the TE_{30} mode which of the following field components exist (i.e. non-zero): (4)

(a) E_x (b) E_y (c) E_z (d) H_x (d) H_y (c) H_z

(4) Which of these modes do not exist in a rectangular cavity: (4)

(a) TE_{110} (b) TE_{011} (c) TM_{110} (d) TM_{111}

(5) In a rectangular waveguide, the cutoff frequency for TE_{02} is 12 GHz. If a = 2b, the cutoff frequency for TM_{11} mode is: (9)

(a) 3 GHz, (b) $3\sqrt{5}$ GHz (3) 12 GHz, (c) $6\sqrt{5}$ GHz (d) None of these.

Problem 4:

A metallic air filled rectangular waveguide operating at 20 GHz in TE mode has the following magnetic field component:

$$E_x = jE_o \sin(\frac{2\pi y}{b}) e^{-0.05z - j\beta z}$$

The waveguide delivers 500 Watt power to the antenna located at the end of the waveguide. Given a = 5 cm and b = 2 cm , the length of the waveguide is 100 cm, and $\sigma_c = 5.8 \times 10^7$ S/m, determine the following

(a) operation mode: (4)

TE_{02}

$$f_c = \frac{u'}{b} = 15GHz$$

(b) The corresponding <u>real</u> electric field for this mode? (6)

$$H_y \neq 0 = \frac{E_x}{\eta} = \frac{jE_o}{\eta} \sin(\frac{2\pi y}{b}) e^{-0.05z - j\beta z}$$

$$H_y(y,z,w,t) = \frac{E_o}{\eta} e^{-0.05z} \sin(\frac{2\pi y}{b}) \sin(\omega t - \beta z)$$

(c) The input power P_{in} : (5)

$$\alpha = 0.05$$

$$P_{in} = P_{out} e^{2\alpha L} = 500 e^{0.1}$$

(d) The power dissipated in the waveguide P_d (5)

$$P_d = P_{in} - P_{out} = (e^{0.1} - 1) x 500$$

(e) The power dissipated in the waveguide P_d when the operation frequency is reduced to 10 GHz? (5)

Frequency f=10 GHz is less than cut-off frequency. No wave propagation. No P_d