The Open University of Sri Lanka
Department of Electrical and Computer Engineering
ECX6233– Microwave Engineering and Applications
Final Examination 2012/2013

Time : 0930 - 1230 hrs. Date: 2013- 08 - 08

Answer any FIVE questions

1.

(a) Write Maxwell's equations. **(4)**

(b) Simplify Maxwell's equations for free space. **(2)**

(c) Using (b), derive an expression for $\nabla \times \nabla \times \underline{E}$ in free space. **(5)**

(d) Using the vector identity $\nabla \times \nabla \times \underline{A} = \nabla(\nabla.\underline{A}) - \nabla^2 \underline{A}$ show that in free space the variation of $\underline{E}$ field satisfies the *wave equation* $\nabla^2 \underline{E} = \frac{1}{c^2}\frac{\partial^2 \underline{E}}{\partial t^2}$ where the constant c is the velocity of propagation of the wave. **(5)**

(e) If $\mu = \mu_0 = 4\pi \times 10^{-7}$ H /m and $\varepsilon = \varepsilon_0 = \frac{1}{36\pi} \times 10^{-9}$ F/m for free space find the speed of electromagnetic wave propagation in free space. **(4)**

2.

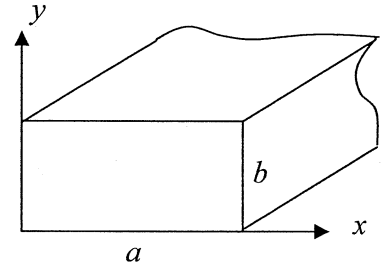
Transverse field components inside a rectangular waveguide are given below:

$$\vec{E}_x = -\frac{jm\beta\pi}{ak_c^2}\vec{A}\cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)e^{-j\beta z}$$

$$\vec{E}_y = -\frac{jn\beta\pi}{bk_c^2}\vec{A}\sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-j\beta z}$$

$$\vec{H}_x = \frac{jn\omega\varepsilon\pi}{bk_c^2}\vec{A}\sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-j\beta z}$$

$$\vec{H}_y = -\frac{jm\omega\varepsilon\pi}{ak_c^2}\vec{A}\cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)e^{-j\beta z}$$



You are required to find the mode of propagation, whether it is *TM* or *TE*.
Let us take it as TX_{mn}.

(a) If $X = M$ what is the dominant mode? **(2)**
(b) If $X = E$ what is the dominant mode? **(2)**
(c) Show that TX_{m0} cannot exist. **(4)**
(d) Show that TX_{0n} cannot exist. **(4)**
(e) What is X, M or E? **(2)**
(f) Find the dominant mode for the above field configuration. **(1)**
(g) Write an expression for H_z. **(2)**
(h) With the help of a diagram briefly explain how the dominant mode can be excited in the waveguide. **(3)**

3.

(a) For a cylindrical waveguide the following field components at $\phi = \phi_0$ are given;

TE mode: $H_z^0 = A_n J_n(\rho k_c)$; $\quad H_\rho^0 = C_1 A_n J_n'(\rho k_c)$;
TM mode: $H_\rho^0 = D_1 B_n J_n(\rho k_c)$; $E_\phi^0 = D_2 B_n J_n(\rho k_c)$;

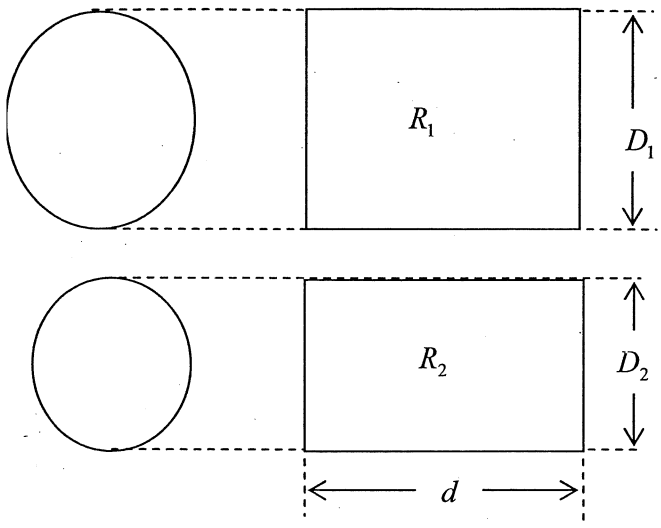
(C_1, D_1, D_2, A_n and B_n are constants)

(i) What are the electromagnetic boundary conditions at a metallic surface? **(3)**
(ii) Using (i) derive an expression for k_c

1. for TE mode. **(5)**
2. for TM mode. **(5)**

(b) The resonant wave length λ_r of a cylindrical resonator oscillating in the n, m, l^{th} mode is given by $\lambda_r = \dfrac{2\pi}{\sqrt{k_c^2 + \left(\dfrac{l\pi}{d}\right)^2}}$, where d is the length of the resonator.

Two air filled cylindrical resonators R_1 and R_2 have the same lengths but different diameters.
R_1 is oscillating in TM_{217} mode and R_2 is oscillating in TE_{237} mode. **(7)**



If the resonant frequencies of R_1 and R_2 are equal, find the ratio of diameters of the resonators, using the Bessel charts given in the Annexure.

4.

(a) (i) Write the scattering matrix of a 3-port junction. **(1)**

(ii) Write the condition that should be satisfied if the junction is losseless. **(2)**

(iii) Write the condition that should be satisfied if the junction is reciprocal. **(2)**

(iv) Write the matrix equation for the junction if it is losseless and reciprocal. **(2)**

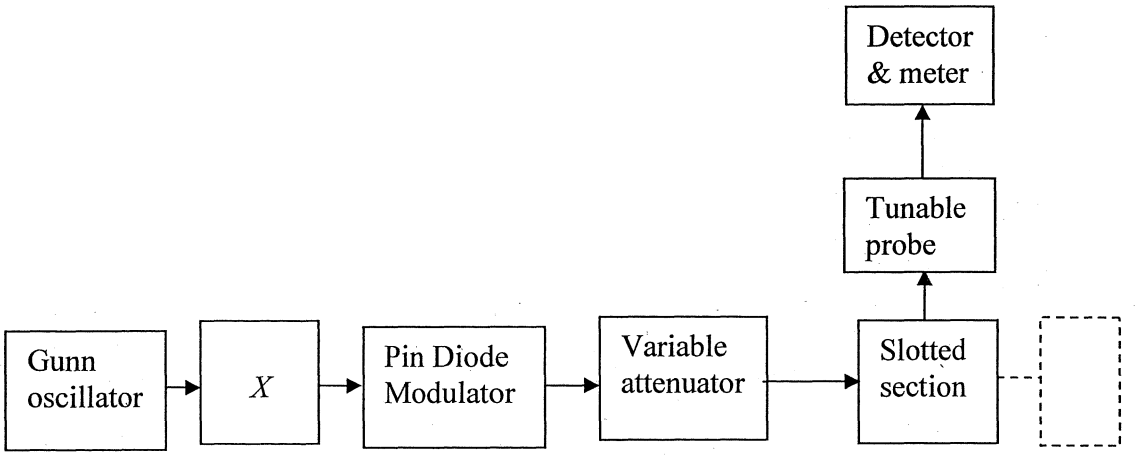
(b) Obtain the [s] matrix for a H-plane T-junction if the main ports 1 and 2 are matched. **(8)**

(c) Draw a H-plane Tee junction.
An electromagnetic wave incident on the auxiliary arm 3 of a H-plane Tee junction splits into two waves in the main arms 1, 2. Show the distribution of E-field in each arm assuming that the mode of propagation is dominant TE mode . **(5)**

5.

(a) Sketch I-V characteristics of a Gunn diode and mark the operating region of a Gunn oscillator. **(4)**

(b) The following setup is used to measure the guide wave length (λ_g) of a slotted rectangular wave guide section:



(i) What is the function of the Pin Modulator? **(2)**

(ii) What is the function of the detector? **(2)**

(iii) What should be the component marked *X*? **(2)**

(iv) What is the function of *X*? **(2)**

(iv) How should the slotted section be terminated? **(2)**

(v) When the tunable probe is moved along the slotted line, the first voltage minimum was observed at a distance $d_1 = 5.4\,cm$. When the probe was moved further, the next voltage minimum was observed at a distance $d_2 = 7.9\,cm$. If the internal measurements of the slotted section are $a = 1.6\,cm$ and $b = 0.8\,cm$, find

1. guide wave length (λ_g). **(2)**
2. cutoff wavelength (λ_c). **(2)**
3. frequency of the Gunn oscillator. **(2)**

Assume that the mode of propagation is TE_{10}.

6.

(a) A certain cellular system consists of 3 clusters with the cluster size 7. Total bandwidth available for the system is 35 *MHz*. The bandwidth of each communication channel (duplex) is 50 *kHz*.

(i) Draw the cellular system and indicate the 3 clusters. **(2)**

(ii) Select any cell on your diagram of (i) above and mark it as A. If the carrier frequency used by A is f_A, mark all the cells that use f_A . (4)

(iii) At a given instant what is the maximum no. of subscribers that can be connected to a particular cell? (4)

(iv) Select any cell on your diagram and mark it as B. Apply 120^0 sectoring to this cell. If co-channel interference is reduced by a factor k due to sectoring find the value of k. (4)

(b) Explain following terms:

(i) Forward Control Channel (3)
(ii) Hand off. (3)

7.

(a) What is signal fading related to mobile communication? (2)

(b) Briefly explain following fading types:

(i) flat fading (2)
(ii) frequency selective fading. (2)

(c) In Rayleigh fading, various parameters are related by the equation

$$N_R = \sqrt{2\pi} f_m \rho e^{-\rho^2} .$$

(i) Define the parameters in the equation. (2)

(ii) A mobile is undergoing Rayleigh Fading while moving. Carrier frequency of the mobile signal is 1.2 *GHz*. If ρ is 0.8 and the maximum Doppler frequency is 16 *Hz*, find

1. positive edge going level crossing rate (3)
2. maximum velocity of the mobile. (3)

(d) What is the difference between *signal scattering* and *signal diffraction*? (3)

(e) With the help of a diagram explain how the *knife edge diffraction* takes place.(3)

8.

(a) In satellite communication a 4-port microwave junction is used to connect the antenna, transmitter and the receiver. What is this junction? **(3)**

(b) Draw a block diagram and explain how the same antenna is used for transmission and reception. **(4)**

(c) (i) With the help of a diagram explain the principle of operation of a Traveling Wave Tube amplifier. **(4)**

(ii) What is the main advantage of this amplifier over klystron amplifier? **(3)**

(d) (i) Briefly explain the role of a *satellite transponder* in a satellite communication system. **(3)**

(ii) How is a satellite transponder powered? **(3)**

Annexture

Properties of Bessel function $J_n(x)$ and it's derivative $J_n'(x)$

k	$J_0(x)$	$J_1(x)$	$J_2(x)$	$J_3(x)$	$J_4(x)$	$J_5(x)$
1	2.4048	3.8317	5.1356	6.3802	7.5883	8.7715
2	5.5201	7.0156	8.4172	9.7610	11.0647	12.3386
3	8.6537	10.1735	11.6198	13.0152	14.3725	15.7002
4	11.7915	13.3237	14.7960	16.2235	17.6160	18.9801
5	14.9309	16.4706	17.9598	19.4094	20.8269	22.2178

Table.1 k^{th} root of $J_n(x) = 0$

k	$J_0'(x)$	$J_1'(x)$	$J_2'(x)$	$J_3'(x)$	$J_4'(x)$	$J_5'(x)$
1	3.8317	1.8412	3.0542	4.2012	5.3175	6.4156
2	7.0156	5.3314	6.7061	8.0152	9.2824	10.5199
3	10.1735	8.5363	9.9695	11.3459	12.6819	13.9872
4	13.3237	11.7060	13.1704	14.5858	15.9641	17.3128
5	16.4706	14.8636	16.3475	17.7887	19.1960	20.5755

Table.2 k^{th} root of $J_n'(x) = 0$