MICROWAVE ENGINEERING
(ECEN 3103)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) In TE_{10} mode of wave propagation in a rectangular waveguide, if the larger dimension of the waveguide is 2 cm, then the cut off wavelength for that mode is:
(a) 40 cm (b) 0.4 cm (c) 4 cm (d) 4 mm.

(ii) X-band frequencies are in which of the following ranges?
(a) 3.5 to 5.5 GHZ (b) 5.5 to 8 GHZ
(c) 8 to 12 GHZ (d) 12.4 to 16.4 GHZ.

(iii) If the loss tangent of a rectangular waveguide is 0.0004, then Q due to dielectric loss is
(a) 1250 (b) 1800 (c) 2500 (d) 2450.

(iv) Scattering matrix for a reciprocal network is:
(a) Symmetric (b) Unitary
(c) Skew symmetric (d) Identity matrix.

(v) A quarter-wave transformer matching a 75Ω source with a 300 Ω load should have a characteristic impedance of
(a) 50 Ω (b) 100 Ω (c) 150 Ω (d) 200 Ω.

(vi) Match list-I with list-II and select the correct answer using the codes given below the lists:
List-I
A. Ratio of maximum energy stored to energy dissipated per cycle
B. TEM mode in a lossless medium
C. Ratio of frequency in radian to phase velocity of EM wave
D. TE_{11} is the mode of lowest cut-off frequency
List-II
1. Propagation constant

2. Cut-off frequency is zero
3. Quality factor of a cavity
4. Cylindrical waveguide

Codes:

	A	B	C	D		A	B	C	D
(a)	3	2	4	1	(b)	2	3	1	4
(c)	3	2	1	4	(d)	2	3	4	1

(vii) In a rectangular waveguide with broader dimension a and a narrow dimension b, the dominant mode of microwave propagation would be
(a) TE_{10} (b) TE_{01} (c) TM_{10} (d) TM_{01}

(viii) Any device with negative impedance as its characteristic property can be called:
(a) Amplifier (b) Energy sink
(c) Oscillator (d) Energy source.

(ix) A two-port non-reciprocal device which produces a minimum attenuation to e.m wave propagation in one direction and a very high attenuation in opposite direction is generally known as
(a) Phase shifter (b) Isolator (c) Polariser (d) Circulator

(x) Transducer power gain of a two-port network is dependent on
(a) Z_S and Z_L (b) Z_S
(c) Z_L (d) Independent of both the impedances

Group – B

2. (a) Represent electric field and magnetic field variation with respect to space with a suitable diagram for dominant mode in a rectangular waveguide. [(CO1, CO2) (Understand/LOCQ)]

(b) A 1-cm X 3-cm rectangular air-filled waveguide operates in the TE_{12} mode at a frequency that is 20% higher than the cut off frequency? Find: (a) the operating frequency, (b) the phase and group velocities. [(C01, C02) (Analyse/IOCQ)]

(c) Design an air-filled cubical cavity to have its dominant resonant frequency at 3 GHz. [(C02) (Create/ HOCQ)]

4 + 4 + 4 = 12

3. (a) Explain degenerate mode of a rectangular waveguide? [(CO2)(Understand /LOCQ)]

(b) In an air-filled rectangular waveguide with a = 2.286 cm and b = 1.016 cm, the y-component of the TE mode is given by $E_y=\sin(2\pi x/a)\cos(3\pi y/b)\sin(10\pi\times10^{10}t-\beta z)$ V/m Find a) operating mode b) Propagation constant c) Intrinsic impedance. [(CO1, CO2)(Analyze/IOCQ)]

(c) Clarify the statement that phase velocity inside a rectangular waveguide is greater than the velocity of light. [(CO2), Understand/LOCQ]

2 + 6 + 4 = 12

Group – C

4. (a) Generate the S matrix for lossless Magic Tee. [(CO3) (Evaluate/ IOCQ])]
   (b) Explain the statement- 'A three port network cannot be simultaneously lossless, reciprocal and matched at all ports. [(CO3) ([Understand/LOCQ)]
   (c) A two-port network has the following s-matrix

$$[S] = \begin{bmatrix} 0.4\angle 0^0 & 0.72\angle -40^0 \\ 0.8\angle 40^0 & 0.2\angle 0^0 \end{bmatrix}$$

   (i) Find return loss at port 2 if port 1 is terminated with a matched load.
   (ii) Find return loss at port 1if the port 2 is terminated with a short circuit load. [(CO3) (Analyze/IOCQ)]

5 + 3 + 4 = 12

5. (a) A 20mW signal is fed into one of the collinear arms of the E plane T junction. Find the power delivered to each port when other ports are terminated with matched load. [(CO3) (Analyze /IOCQ)]
   (b) Find S -matrix for four port symmetrical direction coupler. [(CO3) (Analyze /IOCQ)]

5 + 7 = 12

Group – D

6. (a) What is the main purpose of using helical structure in a traveling wave tube? [(CO4)(Understand /LOCQ)]
   (b) If η_{TE} is the intrinsic wave impedance of TE mode and η_{TM} is the intrinsic wave impedance of TM mode, then prove the relation given below mode $\eta_{TE}.\ \eta_{TM}=\eta^2$ [(CO2)(Analyse/IOCQ)]
   (c) In a rectangular waveguide for which a=1.5cm, b=0.8cm, σ=0, μ=μ_0 and Ɛ =4ε_0,

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

   Determine
   (a) The mode of operation
   (b) The cut off frequency
   (c) The phase constant β
   (d) The propagation constant
   (e) The intrinsic wave impedance. [(CO1) (Evaluate/HOCQ)]

1 + 4 + 7 = 12

7. (a) Explain current voltage relationship of a Gunn diode with a suitable energy band diagram. [(CO4) (Remember/LOCQ)]
   (b) Represent the equivalent circuit for small signal analysis of MESFET. [(CO3) (Understand/LOCQ)]
   (c) Find the transit time of a two-cavity klystron work in 5 GHz with a DC beam voltage 10Kv and 2mm cavity gap. The magnitude of the gap voltage is 100V. [(CO1) (Analyze/IOCQ)]

6 + 3 + 3 = 12

Group – E

8. (a) Differentiate between Butterworth filter and Chebyshev filter. [(CO5) (Understand/LOCQ)]

   (b) State one application of PIN diode. [(CO5) (Remember/LOCQ)]

   (c) Design a microstrip low-pass filter with 2 GHz cut-off frequency, 30 dB attenuation at 3.5 GHz frequency for Chebyshev attenuation response with 0.2 dB ripple. The prototype elements are $g_0 = 1 = g_6$, $g_1 = g_5 = 1.3394$, $g_2 = g_4 = 1.337$, $g_3 = 2.166$. [(CO6) (Create/HOCQ)]

3 + 1 + 8 = 12

9. (a) A microwave transistor has the following S –parameters at 10 GHz, with a 50Ω reference impedances

$S_{11} = 0.45\angle 150^0$

$S_{12} = 0.01\angle -10^0$

$S_{21} = 2.05\angle 10^0$

$S_{22} = 0.40\angle -150^0$

The source impedance is Zs = 20 Ω and the load impedance is Z_L = 30Ω. Find the power gain, the available gain, and the transducer power gain. [(CO5) (Analyze/IOCQ)]

   (b) The S -parameter for GaAs FET at 2 GHz are given below (Z0=50Ω).

$$S_{11} = 0.894\angle -60.6^0$$
$$S_{12} = 3.122\angle 123.6^0$$
$$S_{21} = 0.025\angle 62.4^0$$
$$S_{22} = 0.781\angle -27.6^0$$

Check whether this system is conditionally stable or unconditionally stable. [(CO5) (Evaluate/IOCQ)]

7 + 5 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	28.1 %	41.7 %	30.2 %

Course Outcome (CO):

After the completion of the course students will be able to

1. Apply previous E.M. theory concepts to understand microwave engineering.
2. Identify high frequency electromagnetic wave propagation characteristics through guided media.
3. Analyze microwave passive components and circuits.
4. Students should be able to enhance their knowledge on semiconductor and vacuum tube devices operating at high frequency.
5. Design high frequency filters and amplifiers.
6. Implement the concepts in developing different prototype microwave systems.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question

Department & Section	Submission Link
ECE A	https://classroom.google.com/u/0/w/NDA1MzY3OTcwMDA4/tc/NDY0MjE3NDQ5MjI2
ECE B	https://classroom.google.com/w/NDA1NTk4NDY3MTc4/tc/NDY0MTY3NTY4OTc0
ECE C	https://classroom.google.com/c/NDA1MzM5MTgxOTcy/a/NDU1MTUwMDI4OTky/details
Backlog	https://classroom.google.com/c/NDY0MTk3OTQxNDQ0?cjc=qmdih3d