

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 the two valley model of Gunn diode operation electrons are transferred from
(a) low mobility, high mass lower valley to high mobility, low mass upper valley
(b) high mobility, low mass lower valley to low mobility, high mass upper valley
(c) low mobility, low mass lower valley to high mobility, high mass upper valley
(d) none of these.
- (ii) A quarter-wave transformer matching a 75 Ω source with a 300 Ω load should have a characteristic impedance of
(a) 50 Ω (b) 100 Ω (c) 150 Ω (d) 200 Ω.
- (iii) Calculate the resonant frequency of an air filled rectangular cavity resonator having dimensions a = 3 cm, b = 2 cm, d = 5 cm for TE₁₀₁ mode
(a) 5.834 GHz (b) 6.325 GHz (c) 3.564 GHz (d) 7.432 GHz.
- (iv) In rectangular waveguide (a*b), for dominant mode, the cut-off wavelength is
(a) 2a (b) 2b (c) a (d) b.
- (v) Scattering matrix from a microwave network which is matched at all ports will satisfy the following condition
(a) all matrix element will be zero (b) all diagonal elements will be zero
(c) all non diagonal elements will be zero (d) all diagonal elements will be one.
- (vi) For lossless propagation of EM wave through an unbounded dielectric, the propagation constant is
(a) Real (b) Imaginary (c) Complex (d) None.
- (vii) How many semiconductor layers presents in a PIN diode
(a) 3 (b) 4 (c) 2 (d) 1.
- (viii) When the electric field applied to GaAs specimen is less than the threshold electric field, the current in the material
(a) increases linearly (b) decreases linearly
(c) increases exponentially (d) decreases exponentially.

(ix) Match list-I with list-II and select the correct answer

List-I	List-II
A. Two-cavity klystron	1. High power oscillator
B. Magnetron	2. Low power oscillator
C. TWT	3. Amplifier
D. Reflex klystron	4. Wide band amplifier

A B C D

(a) 4 3 1 2 (b) 3 1 4 2 (c) 4 3 2 1 (d) 3 2 4 1.

(x) When electromagnetic waves are reflected at an angle from a wall, their length along the wall is

- (a) the same as in free space
- (b) the same as the wavelength perpendicular to the wall
- (c) shortened because of reflecting effect
- (d) greater than in the actual direction of propagation.

Group- B

2. (a) Explain why rectangular waveguide cannot support TEM mode wave propagation? [[CO2](Remember/LOCQ)]
- (b) Clearly explain group velocity (u_g), phase velocity (u_p) and medium velocity (u) of wave travelling through a rectangular waveguide with proper diagram and show $u_p \times u_g = u^2$. [[CO2](Analyze/IOCQ)]
- (c) An air filled resonant cavity with dimensions $a = 5$ cm, $b = 4$ cm and $c = 10$ cm is made of copper ($\sigma_c = 5.8 \times 10^7$ S/m). Find five lowest order modes. [[CO1](Analyze/IOCQ)]
2 + 5 + 5 = 12
3. (a) Find the average power for TE_{10} mode inside a rectangular waveguide. [[CO1,CO2](Analyze/IOCQ)]
- (b) Find the relation between loaded and unloaded Q-factor for cavity resonator. [[CO1,CO2](Analyze/IOCQ)]
- (c) 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 cutoff frequency. Determine: (i) the operating frequency and (ii) the phase and group velocities. [[CO1,CO2](Analyze/IOCQ)]
- (d) Explain the statement- "rectangular waveguide cannot support TEM modes." [[CO2](Understand/LOCQ)]
3 + 3 + 4 + 2 = 12

Group - C

4. (a) An x-band directional coupler has a coupling coefficient of 10 dB. What will be the output power in the coupling branch if the input power is 20 mW? [[CO3](Evaluate/HOCQ)]
- (b) A lossless T-junction power divider has a source impedance of 50 Ω . Find out the output characteristic impedances so that the output powers are in a 2:1 ratio. Compute the reflection coefficients seen looking into the output ports. [[CO3] (Analyze/IOCQ)]

- (c) Differentiate between Klystron amplifier and TWTA. [(CO4)(Compare/HOCQ)]
4 + 5 + 3 = 12
5. (a) Derive s-matrix for H plane Tee. [(CO3)(Remember/LOCQ)]
(b) A 20 mW signal is fed into one of the collinear (Port 1) of a lossless H-plane Tee junction. Calculate the power delivered through each port when other ports are terminated in matched load. [(CO3)(Analyze/IOCQ)]
(c) Prove that S-matrix is symmetric for reciprocal network. [(CO3)(Understand/LOCQ)]
5 + 4 + 3 = 12

Group - D

6. (a) Explain mechanism of oscillation of a reflex Klystron with a suitable diagram. [(CO4)(Remember/LOCQ)]
(b) Differentiate between low frequency vacuum tubes and microwave frequency vacuum tubes. [(CO4)(Understand /LOCQ)]
(c) A two cavity klystron operates at 5 GHz with a DC beam voltage of 10 kV and a 2 mm cavity gap. For a given input RF voltage the magnitude of the gap voltage is 100 V. Calculate transit time and angle for this gap. [(CO4)(Analyze/IOCQ)]
7 + 2 + 3 = 12
7. (a) What is the dominant mode of circular waveguide? Draw the dominant mode field distribution in a rectangular waveguide. [(CO1,CO2)(Remember/LOCQ)]
(b) Examine whether the following modes propagate through a standard air filled rectangular waveguide of dimension 7.21 cm × 3.40 cm operating at 5 GHz. TE₀₁, TM₁₁, TE₃₀. [(CO1)(Analyse/IOCQ)]
(c) Prove that all three ports of a reciprocal, lossless 3-port junction can not be matched properly. [(CO3)(Analyse/IOCQ)]
(1 + 2) + 5 + 4 = 12

Group - E

8. (a) 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)]
(b) With I-V characteristic curve describe why Gunn diode is considered to be a TED. [(CO5)(Understand/LOCQ)]
8 + 4 = 12
9. (a) Derive the available power gain for microwave amplifier. [(CO5)(Remember/LOCQ)]
(b) Design a rectangular waveguide with an aspect ratio of 3 to 1 for use in the k band (18-26.5 GHz). Assume that the guide is air filled. [(CO6)(Evaluate/HOCQ)]
8 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	37.5	42.7	19.8

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.