

MICROWAVE ENGINEERING
(ECEN 3103)

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group - A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) The cut off frequency of the dominant mode in a TE wave inside an air filled rectangular waveguide having dimensions 4 cm x 1 cm respectively is
(a) 4 GHz (b) 3.5 GHz (c) 3.75 GHz (d) 2 GHz.
- (ii) In a waveguide, always which condition holds good
(a) phase velocity = 10^6 m/s (b) phase velocity > c
(c) phase velocity = c (d) phase velocity < c.
- (iii) 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) Isolator (b) Circulator
(c) Polariser (d) Phase shifter.
- (iv) In a magic-T when input is given in the E arm, E-plane and H-plane are
(a) In phase (b) Isolated
(c) Out of phase (d) 90° out of phase.
- (v) A major disadvantage of Klystron amplifier is
(a) Low Bandwidth (b) High Power
(c) High Input Impedance (d) Large Bandwidth.
- (vi) A C band directional coupler has an input power of 1 W and the power at the coupled port is 2 mW. The coupling coefficient of directional coupler is
(a) 30 dB (b) 60 dB (c) 27 dB (d) 54 dB.
- (vii) An evanescent mode occurs when
(a) a wave is attenuated rather than propagated
(b) the propagation constant is purely imaginary
(c) $m = 0 = n$ so that all field components vanish
(d) the wave frequency is the same as the cut-off frequency.

- (viii) Degenerate modes define as
 (a) modes having cut off frequency below 10 GHz
 (b) modes having cut off frequency above 10 GHz
 (c) modes having same cut off frequency
 (d) none of the above.
- (ix) Which of the following microwave tube amplifier circuit uses an axial magnetic field and radial electric field?
 (a) Crossed field amplifier (b) Reflex klystron
 (c) TWT (d) None of these.
- (x) Which of the following transmission line structures allow TEM mode of wave propagation?
 (a) Rectangular waveguide (b) Two wire transmission line
 (c) Coaxial cable (d) Both (a) and (c).

Fill in the blanks with the correct word

- (xi) The frequency range for X-band is _____.
- (xii) In TE_{01} mode of wave propagation in a rectangular waveguide, if the narrow wall dimension of the waveguide is 2 cm, then the cut-off wavelength for that mode is _____.
- (xiii) One major disadvantage of Klystron amplifier is _____.
- (xiv) If the reflection coefficient of a 2 port network is 0.5 then the return loss in the network is under matched load _____.
- (xv) If a microwave network is lossless, then S matrix of the microwave network is _____.

Group - B

2. (a) Explain the boundary condition in a rectangular waveguide for TM mode propagation through the guide. Now apply the boundary condition in order to develop the expression of z-component of electric field if the wave is propagating along positive Z direction through the guide. [[CO1,CO2](Analyse/HOCQ)]
- (b) Differentiate between the intrinsic wave impedance of TM mode and TE mode through a rectangular waveguide and develop a relation between them. Show how both of these impedances vary with frequency. [[CO1,CO2](Analyse/HOCQ)]
6 + 6 = 12
3. (a) A rectangular air-filled waveguide having broad wall dimension 8.6 cm and narrow wall dimension of 4.3 cm is fed by a 4 GHz carrier from a coaxial cable. Find out whether the propagation of TE_{10} mode is possible or not. If possible then find out the group velocity and phase velocity. [[CO1,CO2](Analyse/HOCQ)]
- (b) Develop the expression of total average power transmitted across the cross section of the rectangular waveguide for dominant mode. [[CO2](Analyse/IOCQ)]
6 + 6 = 12

Group - C

4. (a) Show that a three port network cannot be simultaneously lossless, reciprocal and matched at all ports. [[CO3](Remember/LOCQ)]
- (b) A magic T-junction is terminated at collinear ports 1 and 2 and difference port 3 by impedances of reflection coefficients $\Gamma_1=0.2$, $\Gamma_2=0.2$, and $\Gamma_3=0.3$, respectively. If 1 W power is fed into sum port 4, calculate the power reflected from port 4 and that transmitted to the other three ports. [[CO3](Analyse/IOCQ)]
- (c) The input power in a directional coupler is 1 mW. The coupler has a coupling coefficient of 15 dB and directivity of 50 dB. Calculate the power at all ports. [[CO3](Analyse/IOCQ)]
- 3 + 6 + 3 = 12**

5. (a) Prove that a reciprocal microwave network must have a symmetric S matrix. [[CO3](Remember/LOCQ)]
- (b) Explain the working principal of circulator. [[CO3](Remember/LOCQ)]
- (c) A two port network has following S-matrix
- $$[s] = \begin{bmatrix} 0.2\angle 0^\circ & 0.6\angle -45^\circ \\ 0.6\angle 45^\circ & 0.1\angle 0^\circ \end{bmatrix}$$
- (i) Determine whether the network is reciprocal and/or lossless?
- (ii) If port 2 is terminated with short circuit load calculate the return loss at port 1. [[CO3](Analyse/IOCQ)]
- 4 + 4 + 4 = 12**

Group - D

6. (a) Draw and explain the slow wave structure of a TWTA. Discuss briefly how the amplification process is taking place inside the TWTA. [[CO4](Remember/LOCQ)]
- (b) With the help of applegate diagram clarify the mechanism of operation of two cavity Klystron amplifier circuit. [[CO4](Remember/LOCQ)]
- 6 + 6 = 12**
7. (a) Explain working function of IMPATT diode with a diagram. [[CO4](Understand/LOCQ)]
- (b) Explain working principle of HEMT and mention why it is suitable for high frequency operation. [[CO4](Understand/LOCQ)]
- 6 + 6 = 12**

Group - E

8. (a) Design a maximally flat low-pass filter with a cut off frequency of 2 GHz, impedance of 50 Ω , and at least 15 dB insertion loss at 3 GHz. Compute and plot the amplitude response and group delay for $f=0$ to 4 GHz, and compare with an equal-ripple (0.3dB ripple) and linear phase filter having the same order. [[CO6](Analyse/IOCQ)]
- (b) Explain unity property and zero property of a lossless N-port network. [[CO3](Remember/LOCQ)]
- 8 + 4 = 12**

9. (a) 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](Create/HOCQ)]
- (b) Evaluate the power gain for two port microwave amplifier network in terms of S-matrix. [[CO5](Evaluate/HOCQ)]
- 5 + 7 = 12**
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Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	40.62	28.13	31.25

Course Outcome (CO):

After the completion of the course students will be able to

Students will come to know about:

CO1. Apply previous E.M. theory concepts to understand microwave engineering.

CO2. Identify high frequency electromagnetic wave propagation characteristics through guided media.

CO3. Analyze microwave passive components and circuits.

CO4. . Students should be able to enhance their knowledge on semiconductor and vacuum tube devices operating at high frequency.

CO5. Design high frequency filters and amplifiers.

CO6. Implement the concepts in developing different prototype microwave systems.

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