RF & MICROWAVE ENGINEERING
(ECEN 4101)

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 a circular waveguide the dominant mode is
(a) TE_{10} (b) TE_{01} (c) TE_{11} (d) TM_{11}.

(ii) A tunnel is modelled as an air-filled metallic rectangular waveguide with dimensions a = 16 m and b = 8 m. Which of the two emergency signals having frequencies 2.9 MHz and 80 MHz can pass through the tunnel?
(a) 2.9 MHz only (b) 80 MHz only
(c) Both of them (d) None of them.

(iii) The distance between two maxima measured using a slotted waveguide is 2 cm. What is the cut-off frequency of the waveguide if it is operating at 1.53 GHz?
(a) 6 GHz (b) 3 GHz
(c) 1.53 GHz (d) None of the above.

(iv) A ferrite is
(a) an inter metallic compound with particularly good conductivity
(b) a non conductor with magnetic properties
(c) an insulator which heavily attenuates magnetic field
(d) a microwave semiconductor invented by Faraday.

(v) In a two-hole directional coupler the distance between two holes are
(a) $l = n^*\lambda_g/2$ (b) $l = (2n + 1)^* \lambda_g/2$
(c) $l = n^* \lambda_g/4$ (d) $l = (2n + 1)^* \lambda_g/4$

(vi) In a reflex klystron, the velocity modulation occurs
(a) in the resonator gap
(b) near the reflector
(c) near the accelerating grid
(d) in between the resonator and the reflector.

(vii) Double Drift Region (DDR) IMPATT diode is preferred to SDR IMPATT, because of
(a) lower noise (b) higher efficiency
(c) higher speed of operation (d) higher frequency range.

(viii) Travelling wave tubes are preferred in radar applications over magnetrons because they have
(a) wide bandwidth
(b) greater efficiency
(c) low noise
(d) capacity to generate large duty cycle.

(ix) The image impedance of a network can be expressed as
(a) $Z_{i1} = \sqrt{\frac{AB}{CD}} \text{and} \sqrt{\frac{BD}{AC}}$ (b) $Z_{i1} = \sqrt{\frac{BD}{AC}} \text{and} \sqrt{\frac{BD}{AC}}$
(c) $Z_{i1} = \sqrt{\frac{AB}{CD}} \text{and} \sqrt{\frac{AD}{BC}}$ (d) $Z_{i1} = \sqrt{\frac{BD}{AC}} \text{and} \sqrt{\frac{AD}{BC}}$

(x) A common example of a 3 dB power divider is
(a) directional coupler (b) magic tee
(c) rat race coupler (d) circulator.

Group – B

2. (a) "Power flow along a waveguide is possible only for real values of the phase constant" — justify the above statement with appropriate arguments.

(b) An air-dielectric L-band rectangular waveguide has a/b = 2 and a dominant-mode cutoff frequency of 0.908 GHz. If the measured guide wavelength is 40 cm, find the guide dimensions, wave number and the operating frequency.

(c) Explain why TEM modes cannot exist within a waveguide.

4 + (2 + 2 + 1) + 3 = 12

3. (a) Derive an expression for different electric and magnetic field components for an electromagnetic wave launched in a rectangular waveguide in TE mode.

(b) Compare between strip line, micro-strip line and fin lines with respect to structure, modes and applications.

8 + 4 = 12

Group – C

4. (a) Prove that it is impossible to construct a perfectly matched, lossless, reciprocal three port junction.

   (b) A two-port network is known to have the following scattering matrix:

   $$\begin{bmatrix} 0.15\angle 0^0 & 0.85\angle -45^0 \\ 0.85\angle 45^0 & 0.2\angle 0^0 \end{bmatrix}$$

   If port two is terminated with an open circuit, what is the return loss seen at port 1?

   (c) Mention few disadvantages of using a quarter wave transformer to match impedances at microwave frequencies.

5 + 4 + 3 = 12

5. (a) A three port circulator has an insertion loss of 1 dB, isolation 30 dB and VSWR = 1.5. Find the S matrix.

   (b) A shunt impedance Z is connected across a transmission line with characteristic impedance Z_0. Find the S matrix of the junction.

   (c) A magic-T is terminated at collinear ports 1 and 2 and difference port 4 by impedance of reflections $\Gamma_1 = 0.5$, $\Gamma_2 = 0.6$ and $\Gamma_4 = 0.8$ respectively. If 1 W power is fed at sum port 3, calculate the power reflected at port 3 and power transmitted to the other three ports.

3 + 4 + 5 = 12

Group – D

6. (a) Draw and explain the high frequency equivalent circuit of a BJT.

   (b) A Gunn diode is working in transit time modes at 12 GHz. The domain of charges move at 10^7 cm/s speed. Calculate (i) the length of the device (ii) can the device work at 10 GHz and 14 GHz. Which is the mode of operation in each case?

6 + 6 = 12

7. (a) With the aid of a schematic diagram, describe the travelling wave tube.

   (b) With the help of graphical plot explain how bunching takes place in a 2-cavity klystron and hence explain its working principle.

   (c) A reflex klystron operates under the following conditions: $V_0 = 575$ V, L = 1 mm, $R_{sh} = 16$ kΩ and f = 10 GHz. If the device is operating at the

peak of $1\frac{3}{4}$ mode, calculate (i) repeller voltage (ii) direct current required to produce gap voltage of 250 V and (iii) efficiency. (Assume that $\beta_0 = 1$, given that at $X' = 1.841$, $J_1(X') = 0.582$)

3 + 5 + (1 + 1 + 2) = 12

Group – E

8. (a) Highlight the need to incorporate redundancies in filter synthesis at microwave frequencies.

   (b) Design a third order low-pass filter in a 50Ω microstrip transmission line system with substrate having $\varepsilon_r = 10$ and height h = 0.65 mm. The cutoff frequency of the filter is desired to be at 1.8 GHz. Assume a 0.5 dB equi-ripple pass-band characteristic.
   (Given for n = 3, the element values are $g_1 = 1.5963$, $g_2 = 1.0967$, $g_3 = 1.5963$ and $g_4 = 1.0$).

2 + 10 = 12

9. (a) Write a short note on stability of transistor amplifiers.

   (b) A microwave transistor has the following S-parameters at 9 GHz, with a 50 Ω reference impedance $S_{11} = 0.42\angle 120^0$, $S_{12} = 0.01\angle -20^0$, $S_{21} = 2.15\angle 20^0$ and $S_{22} = 0.35\angle -120^0$. If the source impedance is 25 Ω and load impedance is 40 Ω, calculate the power gain, available gain and transducer power gain.

6 + (3 × 2) = 12