B.TECH/ECE/7TH SEM/ECEN 4101/2018
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) For a rectangular waveguide to support only the dominant TE mode, which of the following pairs of inequalities has to be satisfied?
(a) $b<\lambda<2b$; $\lambda>2a$ (b) $a<\lambda<2b$; $\lambda>2a$
(c) $b<\lambda<2b$; $\lambda<2a$ (d) $b<\lambda<2b$; $\lambda<2a$.

(ii) A tunnel is modelled as an air-filled metallic rectangular waveguide with dimensions a = 16m and b = 8m. 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) To excite the dominant mode in a rectangular waveguide the coaxial cable is placed at a distance of ___ from the shorted end of the waveguide.
(a) $\lambda_g/8$ (b) $\lambda_g/2$ (c) $\lambda_g/4$ (d) λ_g.

(iv) Passive devices built with ferrite components are
(a) reciprocal and lossless (b) reciprocal and lossy
(c) non-reciprocal and lossless (d) non-reciprocal and lossy.

(v) Due to doubling of the device dimensions its S-matrix changes by a factor of
(a) 2 (b) $1/\sqrt{2}$ (c) ½ (d) does not change.

(vi) A cavity resonator can be represented by
(a) LC circuit (b) lossy inductor
(c) LCR circuit (d) lossy capacitor.

(vii) The power loss of a maximally flat low-pass filter can be expressed as
(a) $1+\epsilon^2\left(\frac{\omega}{\omega_c}\right)^{2N}$ (b) $1+\epsilon^2\left(\frac{\omega}{\omega_c}\right)^{2}$
(c) $1-\epsilon^2\left(\frac{\omega}{\omega_c}\right)^{2N}$ (d) $1+\epsilon^2\left(\frac{\omega_c}{\omega}\right)^{2N}$

(viii) Klystron operates on the principle of
(a) velocity modulation (b) phase modulation
(c) frequency modulation (d) amplitude modulation.

(ix) TWT uses a helix to
(a) reduce noise
(b) ensure broadband operation
(c) increase the efficiency
(d) reduce the axial velocity of RF field.

(x) For Gunn effect, the mobility of the upper valley must be
(a) lower than the lower valley (b) equal to the lower valley
(c) higher than the lower valley (d) none of these

Group – B

2. (a) For a rectangular waveguide, prove that
$$\frac{1}{\lambda_g^2}=\frac{1}{\lambda^2}-\frac{1}{\lambda_c^2}.$$

(b) A rectangular waveguide has width a = 22.86 mm and height b = 10.16 mm. Calculate the phase velocity and group velocity of the dominant TE mode at 20GHz for the rectangular waveguide.

(c) Derive the expression for the cut-off frequency, guided wavelength, phase velocity and group velocity of the TE and TM modes inside a rectangular waveguide. Hence, prove that $V_pV_g = c^2$.

2+ 5 + 5 = 12

3. (a) Determine the length of a rectangular cavity that will operate at 10 GHz in the TE_{101} mode, provided that a = 20 mm and b = 10 mm. Calculate the Q of the cavity if it is made of copper with conductivity of 5.8×10^7 S/m.

(b) What is meant by the quality factor of a cavity resonator? Show that the unloaded, loaded and external q of a cavity are related by the equation
$\frac{1}{Q_{Loaded}}=\frac{1}{Q_{Unloaded}}+\frac{1}{Q_{External}}$. In addition, describe coupling coefficient, under coupling, over coupling and critical coupling.

5 + 7 = 12

Group – C

4. (a) In an H plane tee junction, compute the power delivered to the loads of 40Ω and 60Ω connected to arms 1 and 2 (collinear arms) when a 10 mW power is delivered to the matched port 3.

(b) Explain the working principle of a two-hole directional coupler and derive its S-matrix.

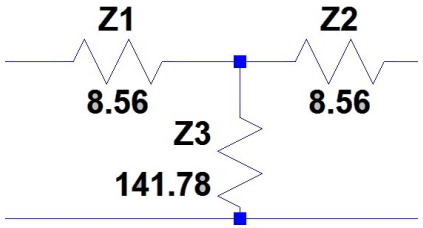
(c) Discuss means of converting a 3-port circulator into a 2-port isolator.

4 + 6 + 2 = 12

5. (a) An amplifier with complex input impedance is connected as the load of a circuit. Discuss means of matching the impedance to a 50Ω transmission line. Is it possible to use quarter-wave transformer in such a situation and why?

(b) List the design steps of a 4-port circulator and write down its corresponding S-matrix.

(c) Determine the S matrix of a 3-dB T-network attenuator terminated in a 50Ω matched load as shown in figure below. (All the values of impedances are in ohms.)



Schematic of a 3-dB attenuator

(3 + 2) +4 + 3 = 12

Group – D

6. (a) Explain the working principle of a reflex klystron. Draw the applegate diagram to indicate velocity modulation.

(b) A two-cavity klystron amplifier operates at 5 GHz with a DC beam voltage of 10kV and a 2 mm cavity gap. For a given input RF voltage, the magnitude of the gap voltage is 100 V. Calculate the transit time at the cavity gap, the transit angle and the velocity of the electrons leaving the gap. (Note $m_e = 9.11\times10^{-31}$kg)

7 + 5 = 12

7. (a) The S-parameters of a certain FET at 4 GHz with a bias voltage V_{gs} = 0 and Z_0 = 50 Ω are as follows: $S_{11} = 0.9\angle-60^0$, $S_{12} = 0.01\angle55^0$, $S_{21} = 3.25\angle130^0$ and $S_{22} = 0.7\angle-25^0$. Determine the stability of the circle.

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

5 + 7 = 12

Group – E

8. (a) With a suitable figure, describe the operating principle of a tunnel diode.

(b) Draw the small signal equivalent of GaAs MESFET. The small signal parameters are R_g =2.8 Ω, R_i = 2.45 Ω, gm = 54Ω^{-1}, Rd = 500 Ω, R_s = 2.45 Ω and C_{gs} = 0.5 pF. Calculate the i) cut-off frequency and ii) maximum operating frequency.

6 + 6 = 12

9. Design a 5th order maximally flat low pass filter with cut off frequency of 2 GHz, impedance of 50Ω. Consider
(g_1 = 0.618, g_2 = 1.618, g_3 = 2, g_4 = 1.618, g_5 = 0.618)

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