SRM Institute of Science and Technology
College of Engineering and Technology

SET-A

DEPARTMENT OF ECE

SRM Nagar, Kattankulathur – 603203, Chengalpattu District, Tamil Nadu

Academic Year: 2022-23 (Even)

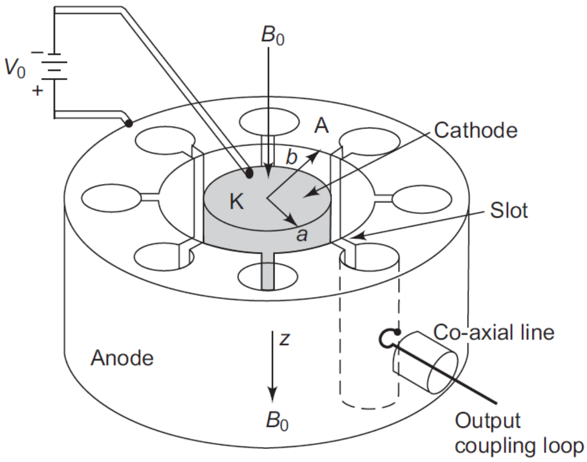
Test: CLAT-1 | **Date: 17-02-2023**
Course Code & Title: 18ECC302J–Microwave and Optical Communication | **Duration: 8.00 AM–9.00 AM**
Year & Sem: III / VI | **Max. Marks: 25**

	18ECC302J - Microwave & Optical Communications	Program Outcomes (POs)														
		Graduate Attributes												PSO		
S. No.	Course Outcomes (COs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	Demonstrate the knowledge on the theory of microwave transmission, microwave generators and associated components	3	-	-	3	-	-	-	-	-	-	-	-	-	-	1
2	Analyse the microwave passive devices and components	-	2	-	3	-	-	-	-	-	-	-	-	2	-	-
3	Incorporate microwave measurements and associated techniques with equipment	-	-	3	2	-	-	-	-	-	-	-	-	-	-	3
4	Gain knowledge of the fundamentals on light transmission through fiber	-	3	-	2	-	-	-	-	-	-	-	-	-	-	1
5	Develop a basic optical communication system	-	3	-	-	3	-	-	-	-	-	-	-	2	-	-
6	Implement the working principle of microwave components, microwave measurements, optical sources, detector and fibers	-	-	3	-	3	-	-	-	-	-	-	-	-	-	3

Part – A
(5 × 3 = 15 Marks)
Instructions: Answer any FIVE Questions.

Q. No.	Question	Marks	BL	CO	PO
1	Name two widely used microwave unipolar transistors and their advantages over microwave bipolar transistors. **Sol:** Microwave unipolar transistors are field-effect transistors (FETs) manufactured from semiconductors incorporating gallium or indium, which have better high-frequency performance due to the higher electron mobility compared to Si. Two commonly used unipolar transistors are: Metal-Semiconductor Field Effect Transistor (MESFET) and High-Electron-Mobility Transistor (HEMT). Their advantages over microwave bipolar transistors: • Microwave unipolar transistors have low noise, and they can replace the parametric amplifiers as the later are expensive and difficult to fabricate. • Only one type of carriers is responsible for the operation of these device, hence these devices are called unipolar. • MESFET can operate in 2–20 GHz range and give a single stage gain of 10–15 dB at 2 GHz with noise figure less than 1 dB. • HEMT can operate up to 100 GHz and give a single stage gain of 6–8 dB at 50 GHz over a bandwidth of 5 GHz and noise figure of 5 dB.	3	1	1	1
2	Explain the operation of a crossed field device in which the dc magnetic field and the dc electric field are perpendicular to each other. **Sol:** Magnetrons are crossed field tubes (M-type) in which the dc magnetic field and the dc electric field are perpendicular to each other. Magnetron consists of a cylindrical cathode *K* of finite-length-radius *a* at the centre	3	1	1	1

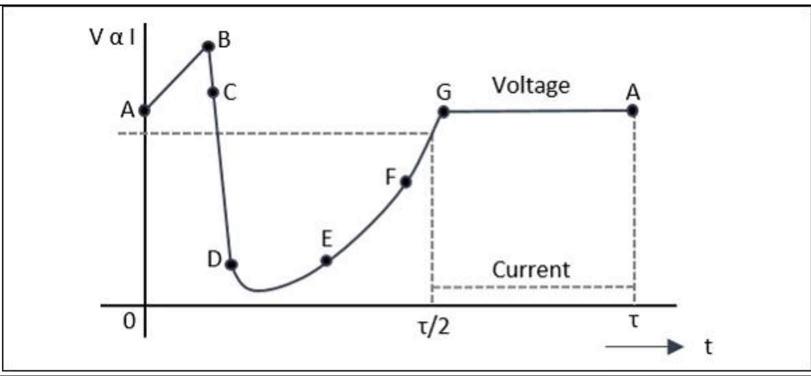
<table>
<tr><td></td><td>surrounded by a cylindrical anode A of radius b. The anode is a slow-wave structure consisting of several re-entrant cavities equispaced around the circumference and coupled together through the anode–cathode space by means of slots. Radial electric field is established by dc voltage V_0 in between the cathode and the anode and an axial dc magnetic flux denoted by B_0 is maintained in the positive z-direction by means of a permanent magnet or an electromagnet. Magnetron theory of operation is based on the motion of electrons under the influence of combined electric and magnetic fi elds. The electrons emitted from the cathode try to travel to the anode. But with the influence of crossed fields E and H in the space between the anode and the cathode, it experiences resultant force $F = -eE - e(v \times B)$, where v is the velocity vector of the electron considered and takes a curved trajectory. Due to excitation of the anode cavities by RF noise voltage in the biasing circuit, the RF field lines are fringed out of the cavity slot to the space between the anode and cathode. The accelerated electrons in the trajectory, when retarded by this RF, field, transfer energy from the electron to the cavities to grow RF oscillations. When the system RF losses balance the RF oscillation energy, a stable oscillation is achieved. Output power is extracted through an external line coupled to the cavity.



<u>Schematic of a magnetron oscillator</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>A class of heavily doped p-n junction diodes with a negative resistance over a portion of their I-V characteristic. Identify the diode and compare it with an ordinary p-n junction diode.

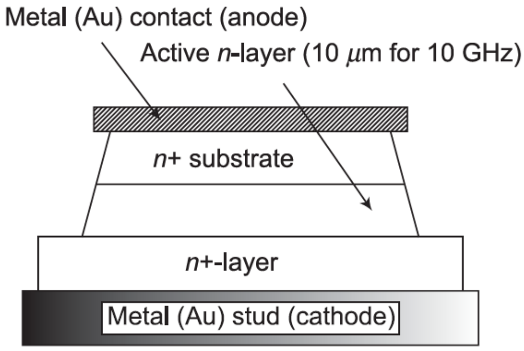
Sol: Tunnel diode
<table>
<tr><th></th><th>Tunnel diode</th><th>Normal p-n diode</th></tr>
<tr><td>1.</td><td>Doping levels at p and n sides are very high.</td><td>Doping is normal in both p and n sides.</td></tr>
<tr><td>2.</td><td>Tunnelling current consists of majority carriers–electrons from n-side to the p-side.</td><td>Current consists of minority carriers—holes from p-side to the n-side.</td></tr>
<tr><td>3.</td><td>Majority carriers current responds much faster to voltage changes—suitable to microwaves.</td><td>Majority carrier current does not respond so fast to voltage changes—suitable for low-frequency applications only.</td></tr>
<tr><td>4.</td><td>At a small value of reverse voltage a large current flows due to considerable overlap between conduction band and valence band—useful as frequency converter.</td><td>Current is extremely small (leakage current) up to considerable reverse bias voltage and then increases abruptly to extremely high at a particular voltage called breakdown voltage.</td></tr>
<tr><td>5.</td><td>Low-power device.</td><td>Lower power device.</td></tr>
<tr><td>6.</td><td>Shows negative resistance characteristics—useful for reflection amplifiers and oscillators.</td><td>Does not show negative resistance—used as detector and mixers.</td></tr>
<tr><td>7.</td><td>It is a low-noise device.</td><td>Moderate noise characteristics.</td></tr>
<tr><td>8.</td><td>Preferred semiconductors are Ge and GaAs.</td><td>Preferred semiconductors are Ge and Si.</td></tr>
</table></td><td>3</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td>4</td><td>Identify a type of Si diode with a $p^+n\, n^+$ (or $n^+ pp^+$) configuration in which the p-n junction is biased beyond the breakdown region. Why does it have</td><td>3</td><td>2</td><td>1</td><td>1</td></tr>
</table>

	a low power dissipation and a high efficiency? **Sol:** TRAPATT diode The TRAPATT diode is mounted inside a coaxial resonator at a position of maximum RF voltage swing. When avalanche occurs at dc reverse-bias plus RF swing beyond the threshold of breakdown, a plasma of holes and electrons are generated. This plasma density results in a high potential difference across the junction in opposition to the dc reverse bias voltage. At this relatively low voltage the plasma gets trapped. But since the external circuit current flow, the voltage rises and the trapped plasma is released producing current pulse across the drift space. The total transit time is the sum of the delay time in releasing the trapped plasma and the drift time. Since the transit time is longer due to low voltage, the operating frequency is limited below 10 GHz. Moreover, the current pulse is associated with low voltage. Therefore, the power dissipation is low and efficiency is higher.				
5	A two-cavity klystron operates at 10 GHz with I_0 = 3.6 mA, V_0 = 10 kV. The drift space length is 2 cm, the output cavity total shunt conductance is G_{sh} = 20 μ mho and beam-coupling coefficient β_2 = 0.92. Find the maximum voltage gain. **Sol:** Maximum voltage gain $A_{\max} = \dfrac{\beta^2 \theta_0 I_0 J_1(X)_{\max}}{XV_0 G_{\text{sh}}}$ dc beam velocity $u_0 = 0.593 \times 10^6 \sqrt{V_0} = 0.593 \times 10^6 \times \sqrt{10} \times 10^3$ $= 0.593 \times 10^8$ m/s Transit angle in drift space $\theta_0 = \dfrac{\omega L}{u_0} = \dfrac{2\pi \times 10 \times 10^6 \times 2 \times 10^{-2}}{0.593 \times 10^8} = 21.19$ rad $A_{\max} = \dfrac{0.92 \times 0.92 \times 21.19 \times 3.6 \times 0.582}{1.841 \times 10 \times 10^3 \times 20 \times 10^{-6}} = 102.1$	3	3	1	4
6	In a microwave transit time device, the application of a current pulse creates a high field avalanche zone that propagates faster than the saturated velocity of the carriers confined in the low field region. Identify the device and explain its various operational regions using a characteristics curve. **Sol:** TRAPATT diode The full form of TRAPATT diode is TRApped Plasma Avalanche Triggered Transit diode. TRAPATTs are high peak power diodes usually *n+-p-p+* or *p+-n-n+* structures with *n*-type depletion region, width varying from 2.5 to 1.25 Âµm. The electrons and holes trapped in low field region behind the zone, are made to fill the depletion region in the diode. This is done by a high field avalanche region which propagates through the diode. The following figure shows a graph in which AB shows charging, BC shows plasma formation, DE shows plasma extraction, EF shows residual extraction, and FG shows charging.	3	1	1	1

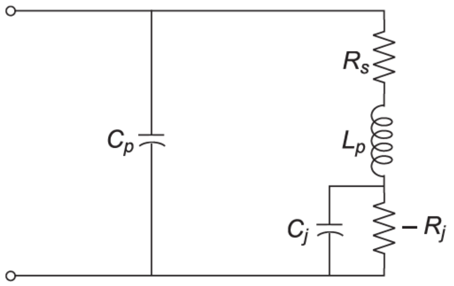
<table>
<tr><td></td><td>
</td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>A transferred electron diode operates in transit time mode and the limited-space-charge mode. Describe its construction details and electrical equivalent circuit.

Sol: Gunn diode

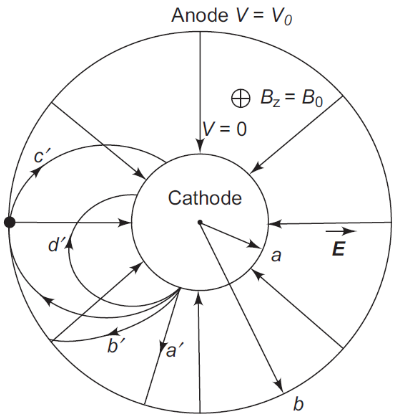
The basic structure of a Gunn diode is shown below, which consists of n-type GaAs semiconductor with regions of high doping (n^+). Although there is no junction, this is called a diode with reference to the positive end (anode) and negative end (cathode) of the dc voltage applied across the device. Since GaAs is a poor conductor, considerable heat is generated in the diode. The diode should be well bonded into a heat sink (Cu-stud).



<u>Structure of a Gunn diode</u>

The electrical equivalent circuit of a Gunn diode is shown below, where C_j and $-R_j$ are the diode capacitance and resistance, respectively, R_s includes the total resistance of lead, ohmic contacts, and bulk resistance of the diode, C_p and L_p are the package capacitance and inductance, respectively.


<u>Equivalent circuit of a Gunn diode</u></td><td>3</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td colspan="6" align="center">Part – B
(1 × 10 = 10 Marks)
Instructions: Answer any ONE Question.</td></tr>
<tr><td>8</td><td>(a) What is mechanical tuning and electronic tuning in a reflex klystron?
(b) How the bunching time can be altered in a reflex klystron?
(c) A reflex klystron is to be operated at a frequency of 10 GHz, with dc</td><td>4
2</td><td>3</td><td>1</td><td>1</td></tr>
</table>

	beam voltage of 300 V, and repeller space of 0.1 cm for 7/4 mode. Calculate P_{RFmax} and corresponding repeller voltage for a beam current of 20 mA. **Sol:** **(a)** Variation in frequency of resonance of cavity by varying its dimension by a mechanical method like adjusting screws is called as mechanical tuning. Variation of frequency by the method of adjusting repeller voltage is called electronic tuning. **(b)** The bunching time of a reflex klystron depends on: • Repeller voltage (V_r) • Repeller distance (L) By varying the parameters V_r and L, the bunching time can be altered in a reflex klystron. **(c)** $P_{RF\max} = \frac{0.398\, V_0 I_0}{N} = \frac{0.398 \times 300 \times 20 \times 10^{-3}}{1\frac{3}{4}} = 1.365 \text{ Watts}$ $\lvert V_R \rvert = 6.74 \times 10^{-6} f_{(\mathrm{Hz})} L_{(\mathrm{m})} \sqrt{V_0}/N - V_0$ $L(m) = 0.1 \times 10^{-2} \text{ m} = 10^{-3} \text{ m}$ $N = 1\frac{3}{4} = 1.75$ $\lvert V_R \rvert = 6.74 \times 10^{-6} \times 10 \times 10^{9} \times 10^{-3} \times \sqrt{300}/1.75 - 300$ $V_R = -367.08 \text{ volts}$	4			
9	A domestic microwave oven uses a cross field device as a source that operates at 2.45 GHz. The radii of the cathode and anode are r_a = 4 cm and r_b = 10 cm, respectively. (a) Identify the microwave source and sketch the electron path in the critical magnetic field. (b) Determine the magnetic flux density required to produce oscillations at 2.45 GHz. (c) Determine the cut-off voltage for the obtained magnetic flux density. **Sol:** **(a)** Magnetron oscillator  <u>Electron path</u> **(b)** Angular frequency (ω_c) = eB_0/m $2\pi f_c = eB_0/m$ $B_0 = 2\pi f_c m/e$	 4 3 3	3	1	4

$$B_0 = 2\pi \times 2.45 \times 10^9 \times 9.109 \times 10^{-31}/1.602 \times 10^{-19}$$

$$B_0 = 0.0875 \text{ Wb/m}^2$$

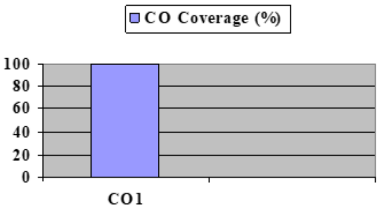
(c)

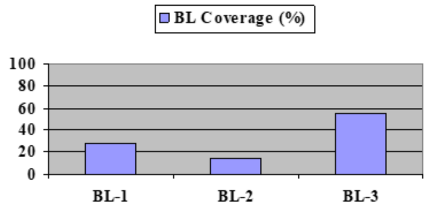
$$\text{The cut-off voltage} = (eB_0^2 b^2/8m)\,(1 - a^2/b^2)^2$$

$$V_c = [\{1.602 \times 10^{-19} \times (0.088)^2 \times (10 \times 10^{-2})^2\}/(8 \times 9.109 \times 10^{-31})] \times$$
$$[1 - \{(4 \times 10^{-2})^2/(10 \times 10^{-2})^2\}]$$

$$V_c = 1.206 \times 10^6 \text{ V}$$

Course Outcome (CO) and Bloom's level (BL) Coverage in Questions





Evaluation Sheet

Name of the Student:

Register No.:

Part - A (5 × 3 = 15 Marks)					
Q. No.	**CO**	**PO**	**Max. Marks**	**Marks Obtained**	**Total**
1	1	1	3		
2	1	1	3		
3	1	1	3		
4	1	1	3		
5	1	4	3		
6	1	1	3		
7	1	1	3		
Part - B (1 × 10 = 10 Marks)					
8	1	1	10		
9	1	4	10		

Consolidated Marks:

CO	Max. Marks	Marks Obtained
CO1	25	

PO	Max. Marks	Marks Obtained
PO1	28	
PO4	13	
Total	41	

Signature of the Course Teacher