Batch 2
SET D

SRM Institute of Science and Technology
College of Engineering and Technology
DEPARTMENT OF ECE

SRM Nagar, Kattankulathur – 603203, Chengalpattu District, Tamilnadu

Academic Year: 2024-2025 (EVEN)

Answer Key of FT-III **Date: 07.04.2025**
Course Code & Title: 21ECC304TR Microwave and Optical Communication **Duration: 12.30 pm – 02.15pm**
Year & Sem.: III & VI **Max. Marks: 50**

Course Articulation Matrix:

	21ECC304TR - Microwave & Optical Communication	Program Outcomes (POs)														
		Graduate Attributes												PSO		
COs	**Course Outcomes (COs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
1	Familiarize the concept of microwave transmission and generation	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
2	Realize systematic methods to design, analyze S-parameters of microwave devices	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
3	Identify different measurement techniques for determining various parameters and to gain knowledge on microwave measurements and the techniques with associated equipment	2	-	-	3	-	-	-	-	-	-	-	-	3	-	-
4	Discover complete information on the fundamentals of light transmission through fiber and their characterization and mechanism	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
5	Recognize the link power budget design considerations of optical communication system	3	-	2	-	-	-	-	-	-	-	-	-	-	2	

Part – A (1x20 = 20 Marks) **Answer all the questions**					
Q. No.	**Question**	**Marks**	**BL**	**CO**	**PO**
1 (a)	i) Provided with the I-V characteristic curves, energy band diagrams, and device physics of GaAs-based microwave diodes, the most accurate reason behind the initiation of microwave oscillations in a Gunn diode when a specific threshold voltage is exceeded; A) The device enters a region where charge carriers are swept away rapidly, leading to carrier depletion and self-oscillation. B) The diode undergoes a reverse bias condition, resulting in Zener-like breakdown across the junction. C) The transferred electron mechanism leads to a region in the I-V curve where an increase in voltage causes a decrease in current, enabling sustained oscillations. D) Impact ionization leads to the generation of secondary carriers, triggering an avalanche of electrons and initiating oscillations. **Ans: C)** The transferred electron mechanism leads to a region in the I-V curve where an increase in voltage causes a decrease in current, enabling sustained oscillations.	1	1	1	1
	ii) Referring to the working principle and timing characteristics of IMPATT diodes, which of the following best explains why they produce high output power but suffer from poor phase noise performance? A) The device relies on multiple energy bands, which causes signal instability. B) The avalanche breakdown process takes time to build up, leading to phase fluctuations in the output. C) High carrier velocity causes rapid oscillations, making frequency locking difficult. D) Excess heat during operation creates unpredictable feedback in the output waveform. **Ans: B)** The avalanche breakdown process takes time to build up, leading to phase fluctuations in the output.	1	1	1	1

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>iii) You are given the S-parameter properties of reciprocal, lossless 3-port microwave networks. Based on the constraints of energy conservation and symmetry, which of the following devices cannot physically exist under these conditions?
A) A circulator that rotates power sequentially between ports with minimal reflection
B) A directional coupler that splits power evenly while maintaining reciprocity
C) A Magic Tee that combines or splits signals using hybrid modes
D) An isolator that permits one-way signal flow between two ports while blocking reverse power

Ans: D) An isolator that permits one-way signal flow between two ports while blocking reverse power</td><td>1</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td></td><td>iv) You are analyzing a microwave network using its S-parameter matrix. In the reference material provided, identify the condition that must hold true for a device to be considered perfectly matched at a given port, ensuring no reflection of the incident wave:

A) The reflection coefficient S_{ii} must be unity, indicating all incident power is reflected.
B) The reflection coefficient S_{ii} must be zero, indicating complete absorption or transmission with no reflection.
C) The reflection coefficient S_{ii} must be −1, signifying total reflection with phase inversion.
D) The reflection coefficient S_{ii} must be j, showing purely reactive mismatch with maximum standing wave ratio.

Ans: B) The reflection coefficient Sii must be zero, indicating complete absorption or transmission with no reflection.</td><td>1</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td>1(b)</td><td>i) (a) Explain the concept of quantum mechanical tunneling and how it influences the conduction process in certain heavily doped semiconductor devices? How does tunneling lead to a negative resistance region in the device characteristics? (5 Marks)

Ans:

Quantum tunneling refers to the process where particles such as electrons pass through a potential energy barrier that they classically should not be able to cross. This occurs due to the wave nature of particles, which allows their wave functions to extend through and beyond thin potential barriers, resulting in a non-zero probability of transmission. (1 mark)

In heavily doped p-n junctions (like tunnel diodes), the depletion region becomes extremely narrow. Due to this, the conduction band of the n-region overlaps with the valence band of the p-region, making tunneling possible at very low voltages. Under unbiased conditions the upper level of the electron energy of both the p-side and n-side are lined up at the same fermi level. Thus net tunnelling on the thin barrier is zero.

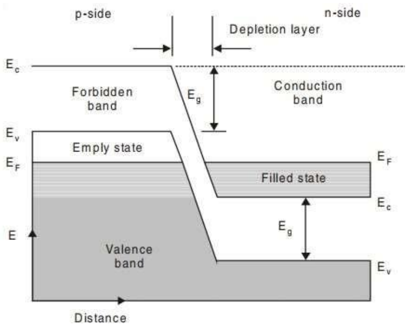
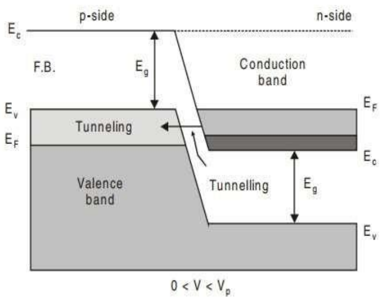


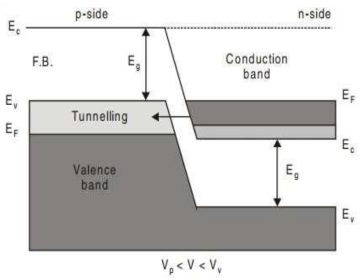
Fig. 7.23. Energy band diagram under no-bias.


Energy band diagram when $0 < V < V_p$.

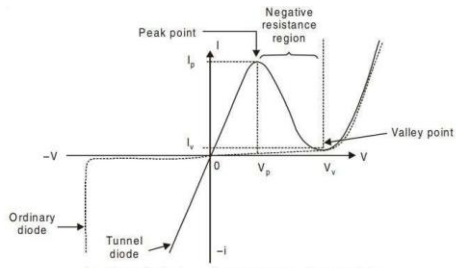
When a small forward voltage is applied, electrons from the filled conduction band states on the n-side tunnel into the empty valence band states on the p-side, resulting in a sharp increase in current. This tunneling current occurs without the need for electrons to gain sufficient energy to surmount the potential barrier. (2 marks)</td><td>8</td><td>3</td><td>1</td><td>1</td></tr>
</table>

Negative Resistance Region:

As the forward bias increases further, the tunneling current rises to a peak (Ip). However, with further voltage increase, the energy band alignment becomes less favorable for tunneling, causing the tunneling current to decrease, creating a negative resistance region in the I-V characteristics. This unique property makes these devices useful in high-frequency applications.



Energy band diagram when $V_p < V < V_v$.



(a) Tunnel diode voltage-current characteristic

(b) Symbol of tunnel diode

. (2 marks)

(b) A high-frequency semiconductor device operates in a material where the electron transit time is 2.5 ps. Calculate the fundamental oscillation frequency of the device. (3 Marks)

Ans:

To find the fundamental oscillation frequency of a high frequency device based on electron transit time:

$$f = \frac{1}{\tau} \quad [\text{where, } \tau = \text{Transit time}]$$

Given; $\tau = 2.5\text{ ps} = 2.5 \times 10^{-12}\text{ s}$

$$\therefore f = \frac{1}{2.5 \times 10^{-12}} = 4 \times 10^{11}\text{ Hz}$$
$$= 400 \times 10^{9}\text{ Hz}$$
$$= 400\text{ GHz}$$

$\therefore$ The fundamental oscillation frequency of the device is 400 GHz.

ii) In a microwave transceiver, a three-port microwave component used that allows power to flow in a specific sequence between ports while preventing reverse flow.

(a) Explain why this device is classified as a non-reciprocal component, and how does it differ from reciprocal microwave devices? Discuss the role of magnetic materials in achieving non-reciprocity in such a device. (5 Marks)

Ans:

The described component is a circulator, a three-port microwave device in which power flows in a fixed circular direction: Port 1→Port 2→Port 3→Port 1

It prevents power from flowing in the reverse direction, making it essential in microwave transceivers for isolating transmitter and receiver paths.

8	3	2	2

Reason for Non-Reciprocal : A circulator is non-reciprocal because the transmission characteristics are not equal in reverse directions: $S_{ij} \neq S_{ji}$

The power from Port 1 goes to Port 2, but not from Port 2 back to Port 1. It instead goes to Port 3. This violates the reciprocity condition typical of many passive devices.

(2Marks)

Difference from Reciprocal Devices:

Reciprocal Devices	**Non-Reciprocal Devices**
$S_{ij}=S_{jj}$	$S_{ij} \neq S_{ji}$
Bidirectional	Unidirectional or cyclic
Coupler, hybrid junction	Isolator, circulator
Not sufficient for isolation	Prevents backflow to sensitive components

(1mark)

Role of Magnetic Materials:
Circulators achieve non-reciprocal behavior using ferrite materials placed in a magnetic bias field. Ferrites under magnetic bias become anisotropic, meaning their permeability differs with direction.
•This leads to non-uniform phase velocity for RF waves traveling in opposite directions.
•As a result, RF energy is rotated inside the device, enforcing the one-way (circulating) power flow.
This mechanism is the basis of non-reciprocity and is not possible without magnetic materials.

(2 marks)

(b) The device is operating at 10 GHz has an input power of 2 W at port 1. The power measured at port 2 is 1.6 W, and the power measured at port 3 is 0.004 W.
-Calculate the insertion loss (in dB) between port 1 and port 2. (3 marks)
-Calculate the isolation (in dB) between port 1 and port 3.

Ans:

Frequency = 10 GHz
$P1 = 2W$
$P2 = 1.6 W$
$P3 = 0.004 W$

– Insertion loss (IL) is the power loss during transmission from input to output.

$$IL(dB) = -10 \log_{10} (P_2/P_1)$$
$$= -10 \log_{10}\left(\frac{1.6}{2}\right)$$
$$= -10 \log_{10} (0.8)$$
$$= -10 \times (-0.09691)$$
$$\simeq \boxed{0.97 \text{ dB}}$$

– Isolation shows how much circulator surpresses unintended signal leakage at Port 3.

$$\text{Isolation (dB)} = -10 \log_{10}\left(\frac{P_3}{P_1}\right)$$
$$= -10 \log_{10}\left(\frac{0.004}{2}\right)$$
$$= -10 \times (-2.69897)$$
$$\simeq \boxed{26.99 \text{ dB}}$$

(insertion loss = 1.5 marks and isolation = 1.5 marks)

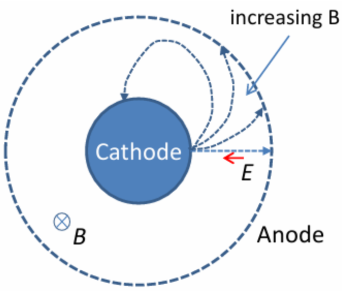
Part – B (2 x 15 = 30 Marks)
Instructions: Answer any two out of three questions

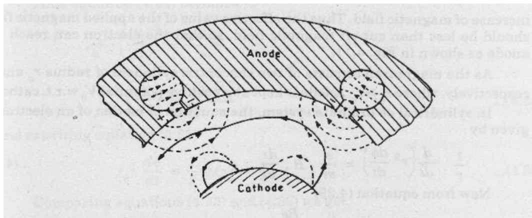
2 (a)		8	3	1	1

i) Explain how crossed electric and magnetic fields in a microwave transmitter for electronic warfare lead to the formation of cycloidal electron trajectories. (3 Marks)

Ans:
The crossed electric and magnetic fields produce cycloidal electron trajectories through the combined effects of linear acceleration and circular motion. Magnetron is a high-power vacuum tube used to generate microwaves. It consists of a central cathode and surrounding anode with resonant cavities.

Magnetron is a crossed field device, in which the magnetic field is applied parallel to the axis of the cylindrical cathode and electrical field is applied perpendicular to the axis of the cathode. The space between the cathode and the anode is the interaction space for the electron (emitted by cathode) & cross field.





Under the magnetic field the electron will rotate in a circular path and at any point this centrifugal force of electron will be balanced by the force exerted by the magnetic field

$$\mathbf{mv^2/r = Bev}$$

or, $$\mathbf{r = (mv/e)/B}$$

So radius of curvature of electron rotation is inversely proportional to the magnetic field.

Under zero magnetic field the electron will move radially outward in a straight path towards the anode. When the magnetic field is very strong the electron will rotate with a very small radius of curvature and will go back to cathode as shown in the figure. Both the type of electron motion are useless for the operation of magnetron. The cycloidal motion allows electrons to:

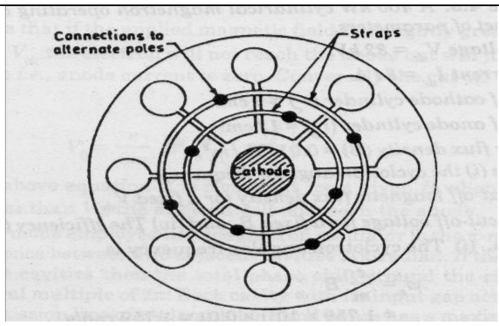
- Interact repeatedly with the RF fields in the resonant cavities
- Create sustained oscillations in the cavities at microwave frequencies

This process is known as "electron bunching", where the cycloidal motion causes electrons to group together and transfer energy coherently to the RF field.

(discussion = 2 marks and diagram = 1mark)

ii) What are strapping and mode separation techniques, and how do they help in stabilizing π-mode operation and why is the π-mode operation preferred in practical magnetron? (5 Marks)

Ans:
strapping and mode separation:
If the frequencies of the different modes of operation are far apart, the magnetron has a tendency of mode jumping during the operation. It can be overcome by using strapping where two ring are connected only to alternate anode poles. At π-mode each ring is at uniform potential but of opposite polarity and thus present a capacitive loading to the cavities, which lowers the frequency. For other modes each ring is not at an uniform potential so that current flows in the rings. This places an inductive loading in the cavities to raise the frequency for other modes.



(4 Marks)

Why is π-mode Preferred:

1. π-mode provides stronger coupling between the electron cloud and RF fields.
2. It ensures synchronous interaction with the bunched electrons following their cycloidal paths.
3. π-mode has a distinct frequency away from other competing modes. (1 Mark)

2 (b) | 7 | 3 | 1 | 2

A radar magnetron operates with an anode voltage of 40 kV and a cathode-anode separation of 3 cm. The required magnetic field is 0.25 T for proper operation.
i) Derive the equation for electron cyclotron frequency. (4 Marks)

Ans:
The Lorentz force acting on a moving electron in a magnetic field is: $F = qvB$

Where:
- F is the force,
- q is the charge of the electron (q = -e),
- v is the velocity of the electron perpendicular to B,
- B is the magnetic field strength.

This force provides the centripetal force required for circular motion:
$F = mv^2 / r$

Equating both expressions: $qvB = mv^2/r$

$\Rightarrow r = mv/(qB)$

The cyclotron angular frequency ω_c is:

$$\omega_c = v/r = qB/m$$

The cyclotron frequency (in Hz) is: $f_c = \omega_c / (2\pi) = qB / (2\pi m)$

For an electron: $q = e = 1.6 \times 10^{-19}$ C and $m = 9.11 \times 10^{-31}$ kg

So, the final expression is: $\mathbf{f_c = \frac{eB}{(2\pi m)}}$

(Derivation = 3marks and Final expression = 1mark)

ii) Calculate the cyclotron frequency for the given magnetic field. (3 Marks)

Ans:

Magnetic field, $B = 0.25\ T$

Charge of electron, $e = 1.6 \times 10^{-19}\ C$

Mass of electron, $m = 9.11 \times 10^{-31}\ kg$.

Cyclotron frequency, $f_c = \dfrac{eB}{2\pi m}$

$$= \frac{1.6 \times 10^{-19} \times 0.25}{2\pi \times 9.11 \times 10^{-31}}$$

$$= \frac{4 \times 10^{-20}}{5.722 \times 10^{-30}}$$

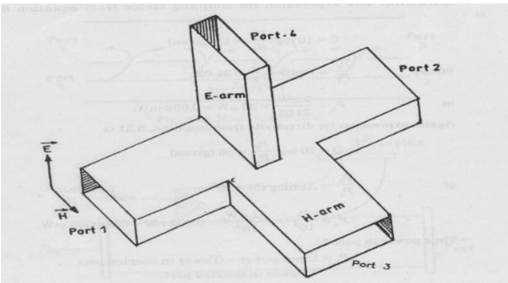
$$\simeq 6.99\ GHz$$

$\therefore \boxed{f_c = 6.99\ GHz}$

(process= 2marks and result = 1mark)

3 (a)	i) Explain the construction of a four-port microwave waveguide junction that consists of two collinear arms and two perpendicular arms. Also derive its S-matrix. (6 Marks)	8	3	2	1

Ans:



Construction:

A four-port microwave waveguide junction with two collinear arms and two perpendicular arms is commonly known as a Magic Tee. It's a hybrid junction that combines the properties of a series (H-plane) tee and a shunt (E-plane) tee.

The Magic Tee is typically constructed using a rectangular waveguide and consists of the following four ports:

1. Port 3 (H-arm): This arm is perpendicularly joined to the broader wall of the main waveguide. It introduces a series connection, meaning the electric fields of waves incident at this port are in phase in the two collinear arms (Port 2 and Port 3). This arm is also called the H-arm because the introduced waveguide is parallel to the magnetic field (H-field).
2. Port 1 (Collinear Arm 1): One of the two arms that are collinear with each other.
3. Port 2 (Collinear Arm 2): The other arm collinear with Port 2.
4. Port 4 (E-arm): This arm is perpendicularly joined to the narrower wall of the main waveguide. It introduces a shunt connection, meaning the electric fields of waves incident at this port are out of phase (180° apart) in the two collinear arms (Port 2 and Port 3). This arm is called the E-arm because the introduced waveguide is parallel to the electric field (E-field).

If powers P1 and P2 are fed through port 1 and 2 respectively then it is added in H-arm, i.e. P1 + P2, while it is subtracted in the E-arm as P1 - P2. Thus, the magic tee can work as a power divider, Power combiner and power subtractor.

S-matrix:

- $S13 = S23 = 1/\sqrt{2}$: signal at Port 3 splits equally into Port 1 and Port 2.
- $S14 = 1/\sqrt{2}$, $S24 = -1/\sqrt{2}$: signal at Port 4 splits equally into Port 1 and Port 2 with a 180° phase difference.
- $S31 = S32 = 1/\sqrt{2}$, $S41 = 1/\sqrt{2}$, $S42 = -1/\sqrt{2}$: reciprocal behavior.
- Diagonal terms (S11, S22, S33, S44) = 0: perfectly matched ports (no reflections).
- The procedure of derivation of the S-matrix considers the symmetry property at the junction for which S14= S41 = S24 = S42, S31 = S13 = –S23 = –S32, S34 = S43 = 0, S12 = S21 = 0.

$$\mathbf{S} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & -1 \\ 1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 \end{bmatrix}$$

(construction = 3marks, diagram = 1mark and S-matrix derivation = 2marks)

ii) If an input power of 10 mW is applied at the horizontal input arm, how is the power distributed among the remaining three ports? (2 Marks)

Ans:

Input power = 10 mW at Port 3 (H-plane port)
From the S-matrix:
$S31 = S32 = 1/\sqrt{2} \rightarrow$ Power splits equally to Port 1 and Port 2.
$S34 = 0 \rightarrow$ No power to Port 4.
Power at Port 1 = $|S31|^2 \times 10 = (1/\sqrt{2})^2 \times 10 = 0.5 \times 10 = 5$ mW
Power at Port 2 = $|S32|^2 \times 10 = (1/\sqrt{2})^2 \times 10 = 5$ mW
Power at Port 4 = 0 mW
Final Power Distribution:
- Port 1: 5 mW
- Port 2: 5 mW
- Port 4: 0 mW

3 (b)	i) Derive and explain any three fundamental properties of the S-matrix for a lossless, reciprocal network. (3marks)	7	3	2	2

Ans:

Fundamental Properties of the S-Matrix :

Reciprocity Property: This property states that if a microwave junction satisfies reciprocity condition in absence of active devices in the circuit then S- parameters are equal to their corresponding transposes.

$$S_{ij} = S_{ji}$$

Unitarity Property: The unity property states that the sum of the products of each term of any one row or column of the matrix S multiplied by its complex conjugate is unity, i.e.,

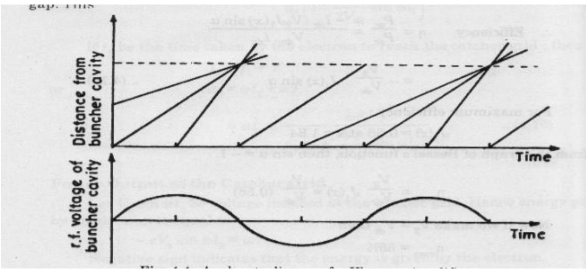
$$\sum_{i=1}^{n} S_{ij} S_{ji} = 1 \text{ for j = 1, 2, 3…., n}$$
$$= |S_{ij}|^2$$

Zero Reflection at Matched Ports: If port i is perfectly matched, no power is reflected, hence the *reflection coefficient is zero.*

$$S_{ii} = 0$$

(each property = 1mark)

ii) An S-parameter measurement shows $S_{21} = 0.89$ and $S_{11} = 0.25$.
(a) Calculate the insertion loss.
(b) Calculate the return loss.
(c) Interpret the result in terms of system performance. (4marks)

<table>
<tr><td></td><td>Ans:
Given; $S_{21} = 0.89$; $S_{11} = 0.25$
(a) Insertion loss (dB) $= -20\log_{10}|S_{21}|$
$= -20\log_{10}(0.89)$
$\simeq \boxed{1.01\ dB}$
(b) Return loss (dB) $= -20\log_{10}|S_{11}|$
$= -20\log_{10}(0.25)$
$\simeq \boxed{12.04\ dB}$
(3 marks)
(c) Interpretation of Results:
Insertion Loss (1.01 dB): Indicates efficient transmission through the network with minimal power loss.
Return Loss (12.04 dB): Suggests about 6.3% of the power is reflected at port 1. Matching is acceptable but could be improved.
(1 mark)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>4
(a)</td><td>i) In an electron beam-based amplifier, electrons are velocity-modulated as they pass through a cavity. Explain how the bunching process takes place and why it is important for amplification.
(5 Marks)
Ans:
Electron beam-based amplifiers, like klystrons use an electron beam to amplify microwave signals.
Velocity Modulation and Bunching:
As the electron beam passes through the input cavity, it encounters an alternating RF electric field. Electrons that enter the cavity when the electric field is in the accelerating phase gain speed. Electrons that enter when the field is retarding lose speed.Electrons that enter at the zero-crossing (neutral phase) continue at their original speed.This variation in electron velocity is called velocity modulation.


After leaving the cavity, the electrons enter a field-free drift space. Faster electrons begin to catch up with the slower ones. Over time, electrons begin to cluster together into "bunches". This transition from a continuous beam to grouped electrons is known as density modulation or bunching. When these bunches reach the output cavity electrons release their energy, resulting in amplification.

Importance of Bunching:
Bunching concentrates electrons into groups, allowing them to transfer energy coherently to the RF field in the output cavity.
This results in a stronger, amplified microwave signal.
Without bunching, electrons would interact randomly, leading to inefficient or no amplification.
(bunching = 3 marks, diagram = 1 mark and importance = 1 mark)</td><td>8</td><td>3</td><td>1</td><td>2</td></tr>
</table>

ii) A microwave amplifier operates with a beam voltage of 5 kV and a beam current of 25 mA. Derive the formula for efficiency and calculate the efficiency if the RF output power is 120 W.

(3 Marks)

Ans:

Given;

Beam Voltage, $V_b = 5 KV = 5 \times 10^3 V$

Beam Current, $I_b = 25 mA = 25 \times 10^{-3} A$

RF output Power; $P_{RF} = 120 W$

Efficiency, $\eta = \frac{\text{RF output Power}}{\text{Input DC Power}} \times 100\%$

$= \frac{P_{RF}}{P_{DC}} \times 100\%$

$= \frac{P_{RF}}{V_b \times I_b} \times 100\%$ $[\because V_b \times I_b = P_{DC}]$

$= \frac{120}{5000 \times 0.25} \simeq 96\%$

$\therefore \boxed{\eta = 96\%}$

(efficiency formulae = 1 mark and result = 2 marks)

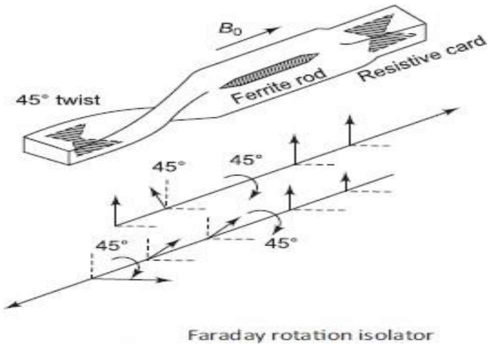
Q. No.	Question	Marks			
4 (b)	i) A bench setup is designed to protect microwave sources from unwanted reflections by providing high isolation in one direction. Explain its construction and working principle. (3 Marks)	7	2	2	2

Ans:

A microwave isolator is a non-reciprocal two-port device that allows microwave signals to pass in one direction only, while absorbing or deflecting signals in the reverse direction.

The key to isolator operation is the non-reciprocal behavior of ferrites under a bias magnetic field:

1. When microwaves enter from Port 1, they interact with the magnetized ferrite.
2. Due to Faraday rotation, the polarization of the wave rotates in a direction determined by the magnetic field.
3. The wave is rotated such that it passes cleanly through to Port 2 with minimal loss.
4. If a wave tries to enter from Port 2, it undergoes further rotation, and its polarization becomes orthogonal to the transmission axis.
5. This reverse wave is absorbed by a resistive load or deflected — not returned to the source.



Faraday rotation isolator

This protects the microwave source from any reflections, ensuring stable and accurate measurements.

(construction =1 marks and working principle = 2marks)

ii) A non-reciprocal microwave device has the following S-matrix:

$$S = \begin{bmatrix} 0 & 0.0001 \\ 1 & 0 \end{bmatrix}$$

(a) Calculate the insertion loss in dB for the forward direction.

(b) Calculate the isolation in dB for the reverse direction. (4 Marks)

Ans:

For a non-reciprocal microwave device,

$$S = \begin{bmatrix} 0 & 0.0001 \\ 1 & 0 \end{bmatrix}$$

~~Hence~~ Here; $S_{11} = S_{22} = 0$ [matched]

$S_{12} = 0.0001$

$S_{21} = 1$

$\therefore S_{12} \neq S_{21}$ [non-reciprocal]

(a) Insertion loss (dB) $= -20 \log_{10}|S_{21}|$

$= -20 \log_{10}(1)$

$= 0$ dB.

(b) Isolation (dB) (in Reverse direction) $= -20 \log_{10}|S_{12}|$

$= -20 \log_{10}(0.0001)$

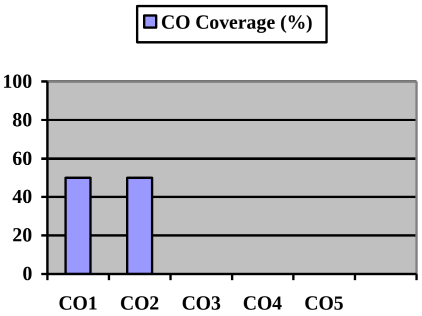
$= -20 \log_{10}(10^{-4})$

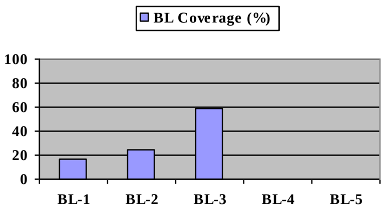
$= -20 \times (-4)$

$= 80$ dB.

. (insertion loss = 2 marks and isolation = 2 marks)

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





Evaluation Sheet

Name of the Student: **Register No.:**

<table>
<tr><th colspan="7">Part- A (1 x 20= 20 Marks)</th></tr>
<tr><th colspan="2">Q. No.</th><th>CO</th><th>PO</th><th>Maximum Marks</th><th>Marks Obtained</th><th>Total</th></tr>
<tr><td rowspan="4">1(a)</td><td>i</td><td>CO1</td><td>1</td><td>1</td><td></td><td rowspan="6"></td></tr>
<tr><td>ii</td><td>CO1</td><td>1</td><td>1</td><td></td></tr>
<tr><td>iii</td><td>CO2</td><td>1</td><td>1</td><td></td></tr>
<tr><td>iv</td><td>CO2</td><td>1</td><td>1</td><td></td></tr>
<tr><td rowspan="2">1b)</td><td>i</td><td>CO1</td><td>1</td><td>8</td><td></td></tr>
<tr><td>ii</td><td>CO2</td><td>2</td><td>8</td><td></td></tr>
</table>

Part- B (2 x 15= 30 Marks)					
2(a)	CO1	1	8		
2(b)	CO1	2	7		
3(a)	CO2	1	8		
3(b)	CO2	2	7		
4(a)	CO1	2	8		
4(b)	CO2	2	7		

Consolidated Marks:

CO	Maximum Marks	Marks Obtained
CO1	33	
CO2	32	
Total	65	

PO	Maximum Marks	Marks Obtained
PO1	28	
PO2	37	
Total	65	

Signature of Course Teacher

Approved by the Course Coordinator

Approved by the Academic Advisor