IV/IV B.Tech (Regular) DEGREE EXAMINATION

NOVEMBER,2019

Seventh Semester

Electronics and Communication Engineering

Microwave Theory and Techniques(14EC703)

SCHEME

Verified by

N. V... 16/11/19

K. Kalpana 16/11/19

Prepared by

K Kalpana

Assistant Professor

ECE DEPT

Mobile No: 9985550585

Verified by

External Examiner

D.JAGADEESH

D. Jaga...

14EC703

Hall Ticket Number:

IV/IV B.Tech (Regular\Supplementary) DEGREE EXAMINATION

November, 2019 — **Electronics and Communication Engineering**

Seventh Semester — **Microwave Theory and Techniques**

Time: Three Hours — **Maximum:** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)
   a) What are the advantages of Microwaves?
   b) Write the applications of cavity resonator.
   c) What is hybrid ring?
   d) What are the properties of S-Matrix?
   e) Give the scattering matrix of E plane Tee.
   f) What is the significance of S-Matrix?
   g) Draw Applegate diagram for Reflex klystron.
   h) What is the use of attenuator in TWT?
   i) What is drift space?
   j) Draw the symbol and structure of varactor diode.
   k) Give the applications of tunnel diode.
   l) What is negative resistance in Gunn diode?

UNIT I

2. a) Discuss the applications of microwaves. 6M
   b) Derive an expression for resonant frequency of a rectangular cavity resonator. 6M

(OR)

3. a) List the IEEE band designations for microwave frequencies. 6M
   b) Explain the operation of Two-Hole directional coupler with neat sketch. 6M

UNIT II

4. a) Derive the scattering matrix for H plane Tee junction. 6M
   b) Find the S-Matrix for a three port circulator with an insertion loss of 1 dB, isolation 30 dB and VSWR of 1. 6M

(OR)

5. a) Obtain scattering matrix for Circulator. 6M
   b) Derive the S-Matrix for Magic Tree. 6M

UNIT III

6. a) Explain the principle of operation of a Reflex klystron tube with neat sketch. 6M
   b) Compare O-type and M-type tubes. 6M

(OR)

7. a) Explain the operation of two-cavity klystron with neat sketch. 6M
   b) Discuss the operation of Cylindrical Magnetron with neat sketch. 6M

UNIT IV

8. a) Discuss the construction and operation of IMPATT diode. 6M
   b) Explain different blocks and features of Microwave Bench. 6M

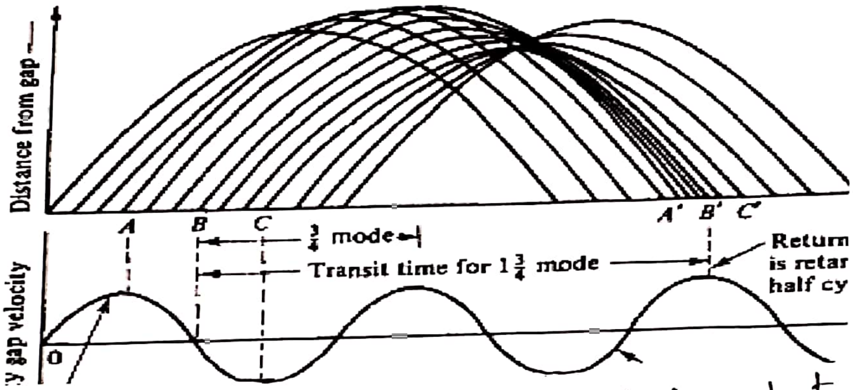
(OR)

9. a) Discuss the construction and working of PIN diode and list its applications. 6M
   b) Explain the measurement of Q of a cavity resonator. 6M

a) High bandwidth capability,LOS propagation and High antenna gain
b) Tuned circuits, duplexers of radars and measuring frequency
c) Hybrid ring is a four port junction and form a complete loop whose median circumference $3\lambda/2$ and can act as power divider and power combiner.
d) (i) Square matrix (ii) unitary property (iii) Reciprocal property (iv) $S_{ii}=0$
e)

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

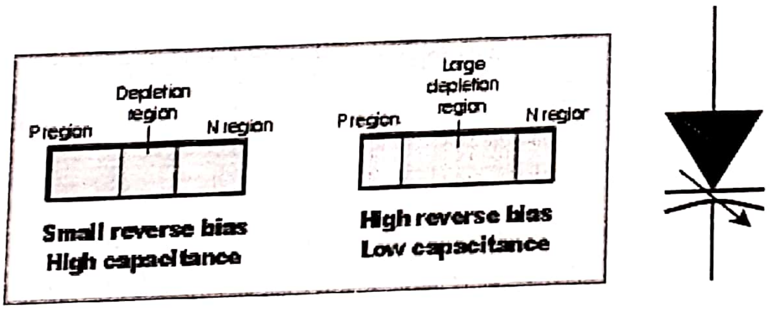
f)It is difficult to get required short and open circuit tests for high frequency thus s parameters gained importance at high frequencies
g)



h) ~~It is used to adjust the power flowing in a waveguide~~ It is used to prevent backward motion of forward wave.

i)The space outside the Buncher grids is called the drift space.

J)



k)Switch, microwave oscillator, memory storage device

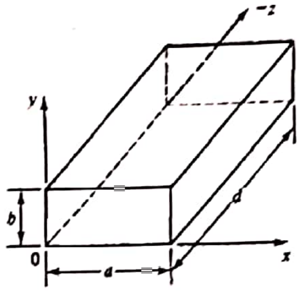
l) When the electric field is beyond the threshold value of 3000 V/cm for the n-typeGaAs,the drift velocity is decreased and the diode exhibits negative resistance.

2a) ANY 6 APPLICATIONS -6M

There are many Industrial, Scientific, Medical and Domestic Applications of Microwaves. *Communication: Remote Sensing. Microwave Oven Medical Science: Defence Applications:Air traffic controlling and Navigation*

2b) DIAGRAM-1M ,EXPLANATION -3M ,EQUATIONS -2M

The electromagnetic field inside the cavity should satisfy Maxwell's equations, subject to the boundary conditions that the electric field tangential to and the magnetic field normal to the metal walls must vanish. The geometry of a rectangular cavity is illustrated



. It is merely necessary to choose the harmonic functions in z to satisfy this condition at the remaining two end walls.

$$H_z = H_{0z} \cos\left(\frac{m\pi x}{a}\right) \cos\left(\frac{n\pi y}{b}\right) \sin\left(\frac{p\pi z}{d}\right) \qquad (TE_{mnp})$$

where $m = 0, 1, 2, 3, \ldots$ represents the number of the half-wave periodicity the x direction
$n = 0, 1, 2, 3, \ldots$ represents the number of the half-wave periodicity the y direction
$p = 1, 2, 3, 4, \ldots$ represents the number of the half-wave periodicity the z direction

and

$$E_z = E_{0z} \sin\left(\frac{m\pi x}{a}\right) \sin\left(\frac{n\pi x}{b}\right) \cos\left(\frac{p\pi z}{d}\right) \qquad (TM_{mnp})$$

where $m = 1, 2, 3, 4, \ldots$
$n = 1, 2, 3, 4, \ldots$
$p = 0, 1, 2, 3, \ldots$

The separation equation for both TE and TM modes is given by

$$k^2 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{p\pi}{d}\right)^2$$

For a lossless dielectric, $k^2 = \omega^2\mu\epsilon$; therefore, the resonant frequency is expressed by

$$f_r = \frac{1}{2\sqrt{\mu\epsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2} \qquad (TE_{mnp}, TM_{mnp})$$

For $a > b < d$, the dominant mode is the TE_{101} mode.

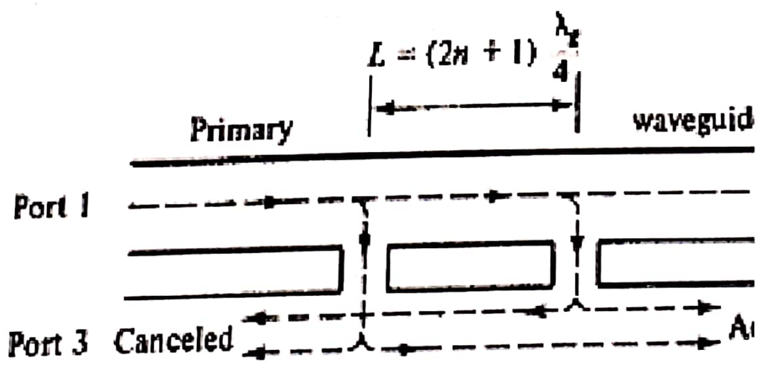
3a) **BANDS-3M, FREQUENCY RANGE -3M**

	Letter band designator	Frequency range (GI
Microwave Region	L	1 to 2
	S	2 to 4
	C	4 to 8
	X	8 to 12
	K_u	12 to 18
	K	18 to 26
	K_a	27 to 40
limeter Region	V	40 to 75
	W	75 to 110
	Millimeter waves	30 to 300

3b) **Diagram -2M , Explanation-4M**

A directional coupler is a four-port waveguide junction . It consists of a primary waveguide 1-2 and a secondary waveguide 3-4. When all ports are terminated in their characteristic impedances, there is free transmission of power, without reflection, between port 1 and port 2, and there is no transmission of power between port 1 and port 3 or between port 2 and port 4 because no coupling exists between these two pairs of ports. The degree of coupling between port 1 and port 4 and between port 2 and port 3 depends on the structure of the coupler. The spacing between the centers of two holes must be

$$L = (2n + 1)\frac{\lambda_g}{4}$$



4a) **EQUATIONS -4M,S-MATRIX-2M**

Working:If two input waves are fed into port 1 and port 2 of the collinear arm, the output wave at port 3 will be in phase and additive. On the otherhand, if the input is fed into port 3, the wave will split equally into port 1 and port 2 in phase and in the same magnitude.

The properties of H-Plane Tee can be defined by its $[S]_{3\times3}$ matrix.

It is a 3×3 matrix as there are 3 possible inputs and 3 possible outputs.

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix}$$ .... **Equation 1**

Scattering coefficients S_{13} and S_{23} are equal here as the junction is symmetrical

From the symmetric property,

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

$$S_{12} = S_{21} \quad S_{23} = S_{32} = S_{13} \quad S_{13} = S_{31}$$

Now, the $[S]$ matrix can be written as,

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{12} & S_{22} & S_{13} \\ S_{13} & S_{13} & 0 \end{bmatrix}$$ .... **Eq**

We can say that we have four unknowns, considering the symmetry property.

From the Unitary property

$$[S][S]* = [I]$$

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix} \begin{bmatrix} S_{11}^* & S_{12}^* & S_{13}^* \\ S_{21}^* & S_{22}^* & S_{23}^* \\ S_{31}^* & S_{32}^* & S_{33}^* \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

We get,

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

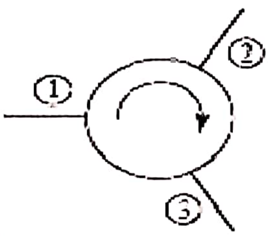
4b) **EQUATIONS-3M ,ANSWERS-3M**

Insertion loss=-20logS_{21} : Isolation loss =-20logS_{12} : Reflection coefficient=s-1/s+1

S_{21}=0.89 S_{12}=0.0316 S_{11}=S_{22}=S_{33}=0

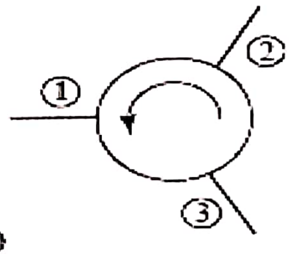
5a) **DIAGRAMS-2M EXPLANATION-2M S-Matrix-2M**

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



(a)

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



(b)

a) Clock wise cirulator and S-matrix b) counter clock wise circulator

The only difference between the two cases is in the direction of power flow between the ports. The solutions for Clock wise cirulator solutions corresponds to a circulator that allows the power flow only from port1 to port2, or port2 to3. Or port 3 to1. The solution for counter clock wise corresponds to a circulator with the opposite direction of the power flow.

5b) **EQUATIONS -4M,S-MATRIX-2M**

A magic tee is a combination of the E-plane tee and H -plane tee

It is a 4×4 matrix as there are 4 possible inputs and 4 possible outputs.

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}$$ .... **Equa**

As it has H-Plane Tee section

$$S_{23} = S_{13}$$ .... **Equat**

As it has E-Plane Tee section

$$S_{24} = -S_{14}$$ .... **Equati**

The E-Arm port and H-Arm port are so isolated that the other won't deliver an output, if a one of them. Hence, this can be noted as

$$S_{34} = S_{43} = 0$$ .... **Equatio**

From the symmetry property, we have

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

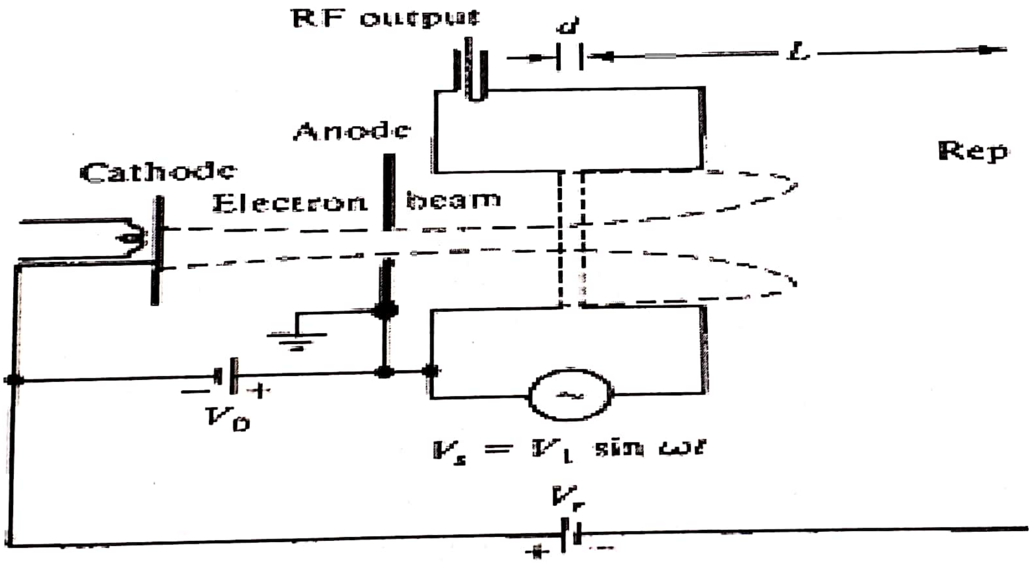
From Unitary property, $[S][S]^* = [I]$

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{12} & S_{22} & S_{13} & -S_{14} \\ S_{13} & S_{13} & 0 & 0 \\ S_{14} & -S_{14} & 0 & 0 \end{bmatrix} \begin{bmatrix} S_{11}^* & S_{12}^* & S_{13}^* & S_{14}^* \\ S_{12}^* & S_{22}^* & S_{13}^* & -S_{14}^* \\ S_{13} & S_{13} & 0 & 0 \\ S_{14} & -S_{14} & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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

6a **DIAGRAM-2M EXPLANATION-4M**



The working of reflex klystron is somewhat similar to the working of two-cavity klystron. So, working principle of reflex klystron is velocity and current modulation. So, electron beam is injected from the cathode and that injected beam travel with a uniform velocity till the cavity. And in the cavity gap, the velocity of the electrons is modulated. And those velocity modulated electrons enter the repeller space with different velocities and because of the velocity modulation and repulsive forces from the repeller plate the bunching takes place in the return journey of the electron to the cavity. Because of the bunch formation there will be current modulation in the cavity. The timing of this bunching should be such that the phase of gap voltage should be retarding. This is done to ensure the maximum power transfer from electrons to the cavity. So, because of this power transfer there will be oscillations. So, this is how oscillations are sustained

.

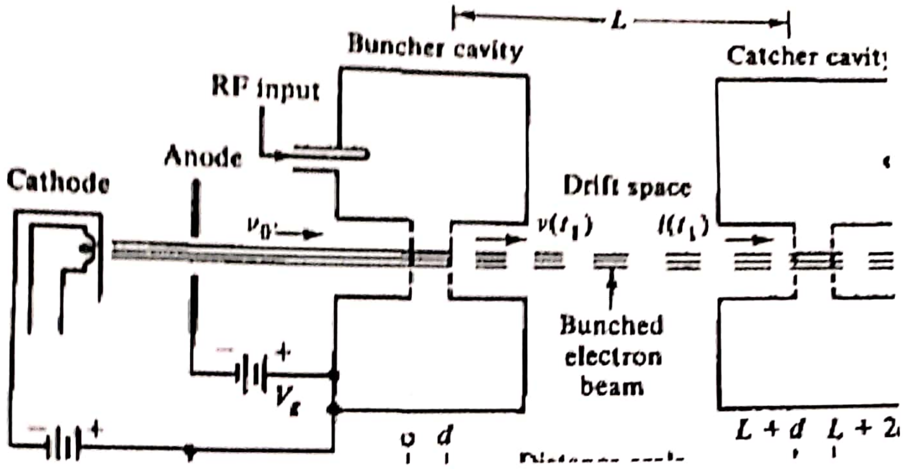
Any 4

6b)6 Differences-6M

M type Tubes	O type Tubes
The electron beam is perpendicular to both electric and magnetic fields	In linear beam tubes the electron beam travels along a straight path between cathode and collector
Static magnetic field is perpendicular to the electric field	Static magnetic field is same direction to the electric field
Magnetron is the M type Tube	Klystron and TWT are the O type tubes
Electron travel in curved path	Electron travel in linear path
Efficiency and output both are high	Moderate efficiency and Moderate output
Noise is high	Noise is low

7a) **DIAGRAM-3M EXPLANATION-3M**

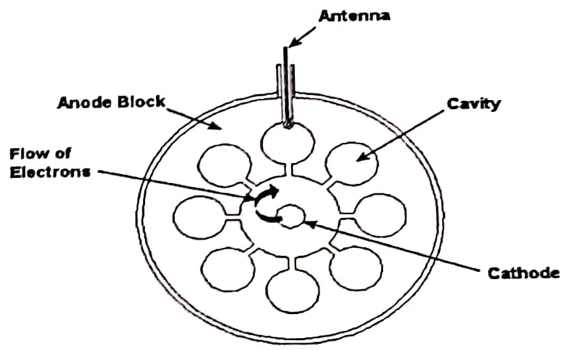
The two-cavity klystron is a widely used microwave amplifier operated by the principles of velocity and current modulation. All electrons injected from the cathode arrive at the first cavity with uniform velocity. Those electrons passing the first cavity gap at zeros of the gap voltage (or signal voltage) pass through with unchanged velocity; those passing through the positive half cycles of the gap voltage undergo an increase in velocity; those passing through the negative swings of the gap voltage undergo a decrease in velocity. As a result of these actions, the electrons gradually bunch together as they travel down the drift space. The variation in electron velocity in the drift space is known as velocity modulation. The density of the electrons in the second cavity gap varies cyclically with time. The electron beam contains an ac component and is said to be current-modulated.



The kinetic energy is transferred from the electrons to the field of the second cavity.

7b)**DIAGRAM-2M EXPLANATION-4M**

It is a diode with eight re entrant cavities and is concentric with an oxide coated cathode. A permanent magnet was used for applying a magnetic field that is parallel to the cathode surface.In the anode block a number of holes and slots act as resonant anode cavities.



Operation

The cavity magnetron has 8 cavities that are tightly coupled to each other .A N-cavity tightly coupled system will have N-modes of operation each of which is uniquely characterized by a combination of frequency and phase of oscillation relative to the adjacent cavity .In addition these modes must be self consistent so that total phase shift around the ring of cavity resonators is $2n\pi$ where n is integer.The minimum phase shift should be 45^0

The relative phase change $\phi_v = 2\pi n/N$

Case 1: If n=N/2 $\phi_v = \pi$ This mode is called π mode

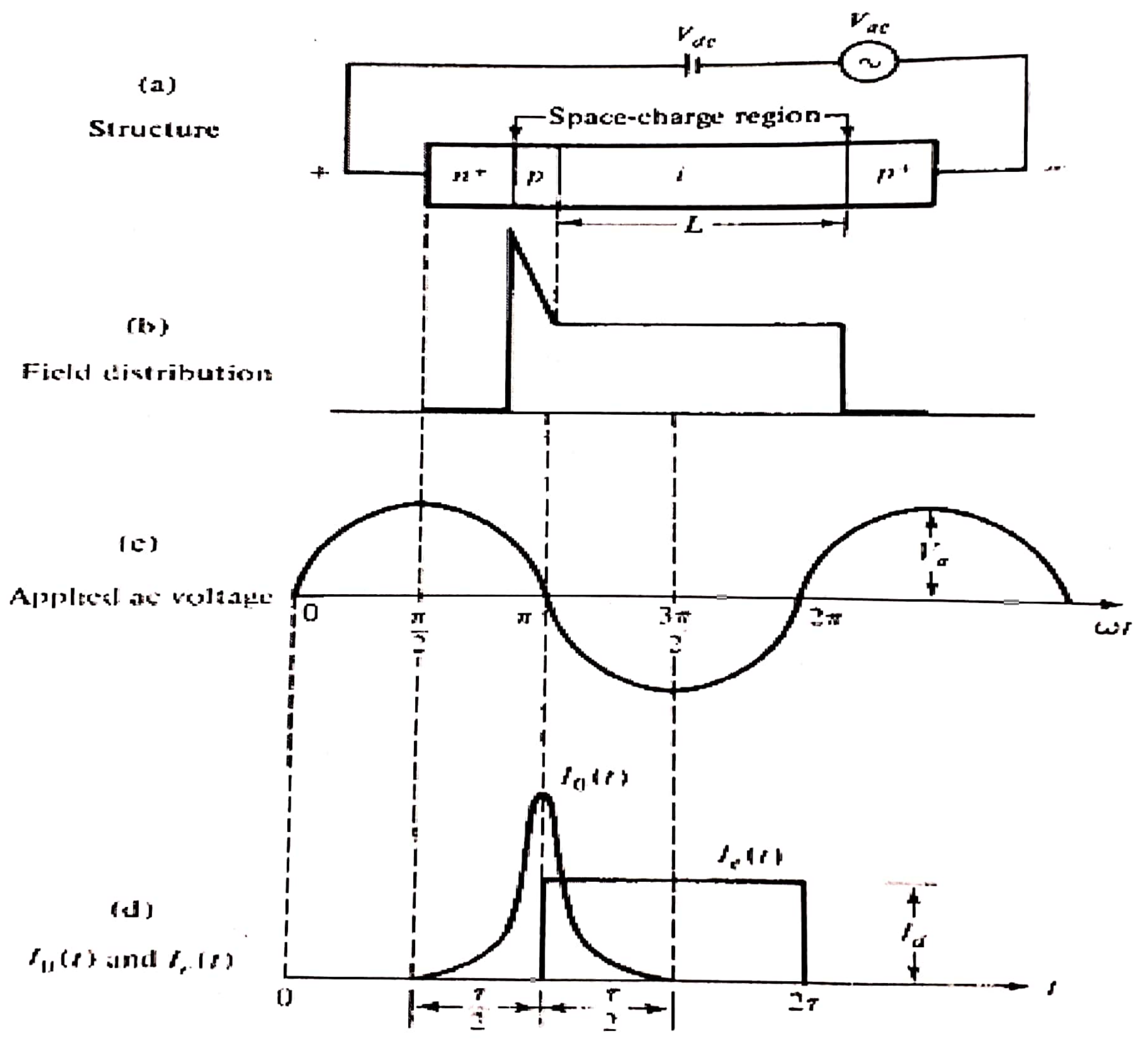
Case 2: If n=0, $\phi_v = 0$. Which means there will be no RF electric field between anode and cathode

8a) **DIAGRAM-3M EXPLANATION-3M**

Impatt diodes :These diodes exhibit a differential negative resistance by two effects:

1. The impact ionization avalanche effect, which causes the carrier current fo(t) and the ac voltage to be out of phase by 90°

2. The transit-time effect, which further delays the external current *I.(t)* relative to the ac voltage



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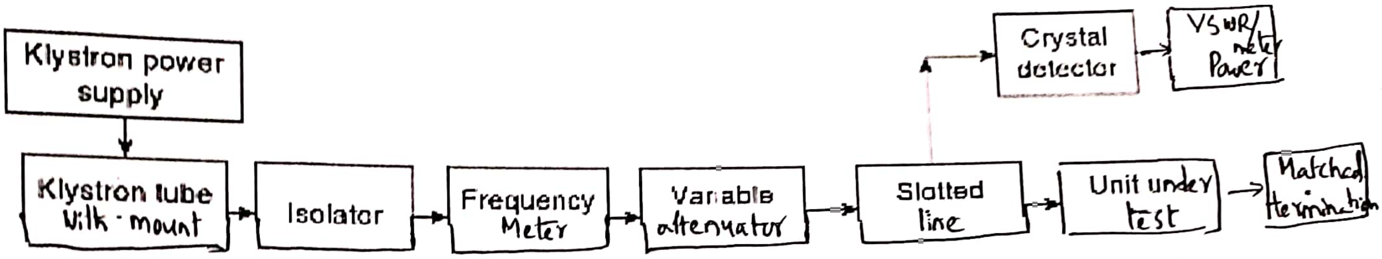
8b) BENCH-2M, EXPLANATION-4M



Signal Generator:As the name implies, it generates a microwave signal, in the order of a few millivolts. A Gunn diode oscillator or a Reflex Klystron tube could be an example for this microwave signal generator.

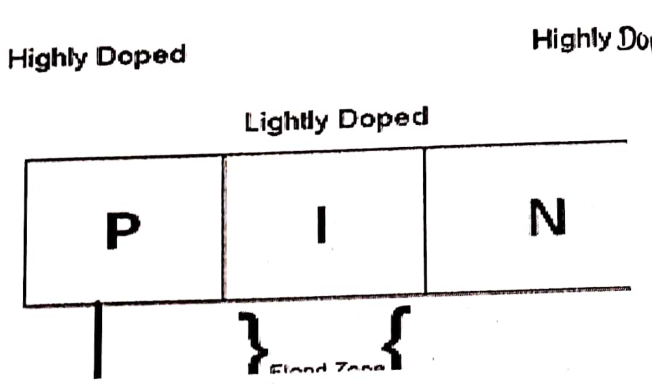
Isolator :It allows the signal to pass through the waveguide only in one direction.

Precision Attenuator :It adjusts the power flowing in a wave guide.They can be either fixed or variable attenuator

Frequency Meter: This is the device which measures the frequency of the signal. With this frequency meter, the signal can be adjusted to its resonance frequency.

Slotted line used for measuring standing wave ratio.A crystal detector is inserted in the probe and is used to adjust the modulated signal by sensing the relative field strength of standing wave pattern in the wave guide.

9a) PIN Diode-DIAGRAM-2M EXPLANATION-4M



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Operation: Upto 100 MHz the operation is similar to ordinary p-n junction diode.At higher frequencies the PIN diode acts as variable resistance.Under zero and reverse bias the diode has a very high impedance at microwave frequencies and a very low impedance for small forward currents i.e. It behaves as microwave switch

9b) (MICROWAVE BENCH-2M, EXPLANATION-4M)

A volume that is completely surrounded by a metallic surface is defined as a *cavity*. The important parameter of a cavity is quality factor. It is a measure of selectivity of the frequency resonant or anti-resonant circuit and is defined by the following equation:

$$Q = 2\pi \frac{\text{Maximum energy stored in resonant circuit}}{\text{Energy stored per cycle}}$$

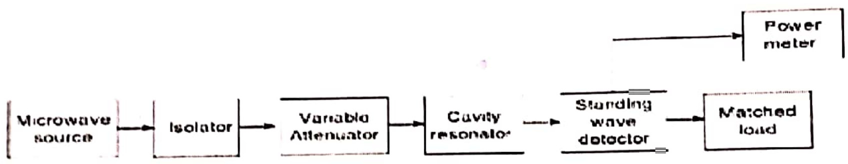
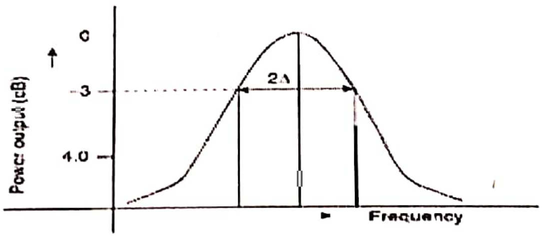


Figure *Bench setup for measurement of Q by transmission method*

The cavity resonator is used as a transmission device, in this method, and the output power is measured as a function of the frequency resulting in the resonance curve



The output power is to be measured by two methods

(i) Changing the frequency of the source of the microwave and by keeping the signal level constant.

(ii) Tuning the cavity and by keeping both signal level and frequency constant, the output power is measured. The half-power bandwidth can be calculated (2Δ) from the resonance curve in the Figure 11.24.

$$2\Delta = \pm\left(\frac{1}{Q_l}\right)$$

$$Q_l = \pm\left(\frac{1}{2\Delta}\right) = \pm\left(\frac{\omega}{2(\omega - \omega_0)}\right)$$

where Q_L – loaded value

Q_0 = unloaded Q

$Q_l = Q_0$ if the coupling between microwave source and cavity and that between detector and cavity are neglected.