Subject : Microwave engineering and optical communica

Q.P. Code : A0424206R0623

For Office Use 12424172

VALUATION-II

Q.No.	1	2	3	4	5	6	7
A							
B							
C							
D							
E							
F							
G							
TOTAL							

GRAND TOTAL

(in words)

Signature of the Examiner

Signature of the Scrutinizer

Subject : Microwave engineering and optical communic

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VALUATION-I

Q.No.	1	2	3	4	5	6	7
A	0	12		8	6	6	6
B	2			5	4	5	6
C	1						
D	2						
E	1						
F	2						
G	2						
TOTAL	10	12		13	10	11	12

GRAND TOTAL 58

(in words) FIVE EIGHT

Signature of the Examiner

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2 **Reflex Klystron :**

In Microwave there are two types of beam tubes

1) ~~cros~~ Linear Beam tubes (or) 'o' - type tubes (original)

2) crossed ~~Be field~~ Beam tubes (or) 'M' - type tubes (Modified)

3) The Reflex Klystron is a part of linear field tubes (or) 'o' - type tubes. this means the electric field and magnetic fields are perpendicular to each other.

4) The following figure represents operation of reflex klystron

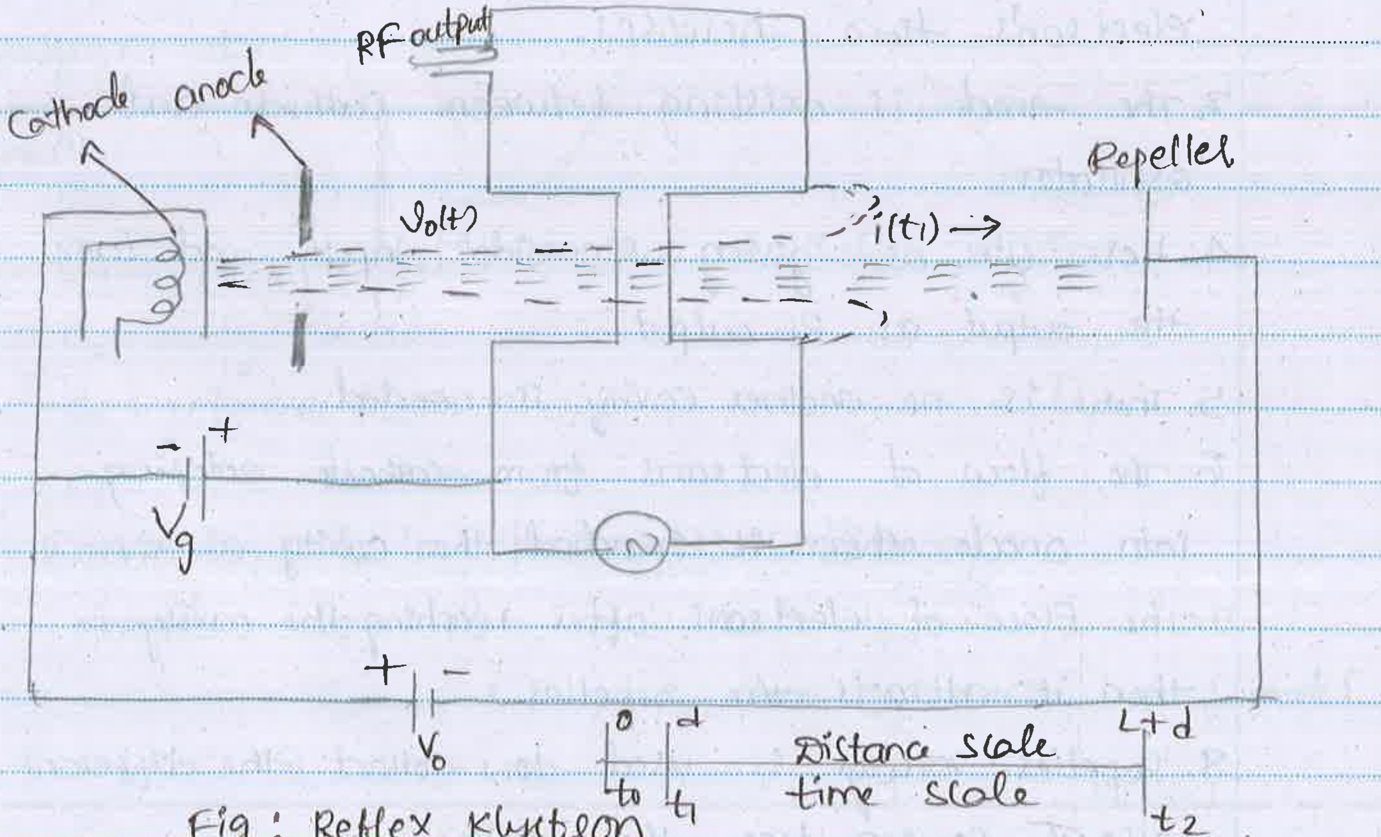

Fig : Reflex Klystron

Construction:

Consider one-cavity reflex klystron it is having only output path. So consider cathode filament connected to a battery.

The Repeller also connected to a battery.

Anode represents catching of electrons from cavity

Working:

1. It is an oscillator. (Reflex klystron oscillator)
2. Cathode releases some heat due to that heat electron's flow increases.
3. The Anode is existing between cathode and oscillator
4. Here we are giving sinusoidal input and takes the output as RF output
5. There is no another cavity is needed.
6. The flow of electrons from cathode entering into anode then it reached the cavity at V_0.
7. The Flow of electrons after reaching the cavity i_0 then it attracts the repeller.
8. Repeller voltage is used to collect the different voltages coming from the cavity.
9. Here velocity modulation and current modulation occurs

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Q.No	

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5

velocity modulation: The process of changing the velocity of the electron between the cavity by the sinusoidal signal (or) RF signal.

current modulation: A point at which where bunching process happening.

→ The following represent Apple gate diagram of Reflex Klystron

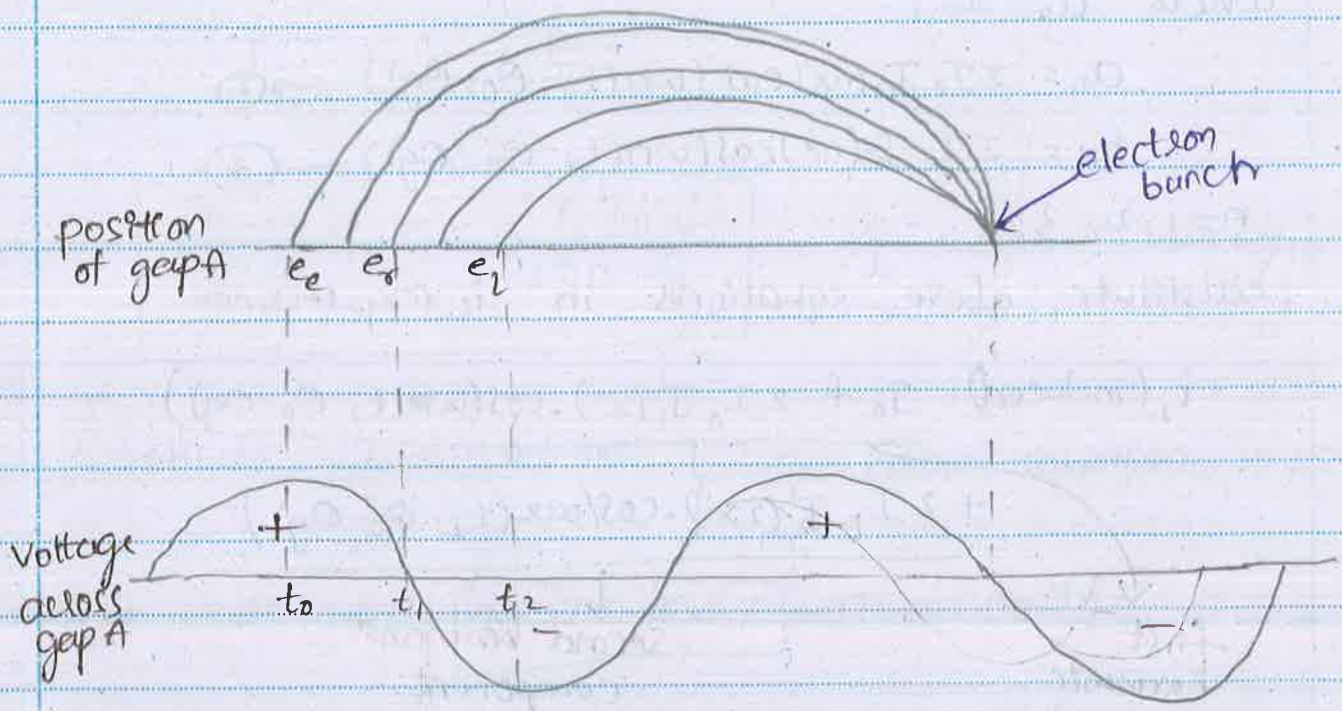

Fig: Apple gate diagram of Reflex Klystron

e_e = early electron

e_r = reference electron

e_l = late electron

Derivation ~~to~~ for finding the efficiency:

consider $\theta_0 = \omega T_0$ $\qquad 2\pi(n - \frac{1}{4})$

$T_0 = t_1 - t_0$ $\qquad 2\pi n - \frac{\pi}{2}$ Here $n = \frac{1}{3}$ modes

$\theta_0 = \omega t_1 - \omega t_0$ $\qquad (n - \frac{1}{3})$

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Q.No	Marks

$$i_2\,(\text{induced}) = a_0 + \sum_{n=1}^{\infty} 2 I_0 J_n'(nx') \cos(\omega n(t_2 - \theta_0 - \theta_g)) \longrightarrow (1)$$

where $a_0 = I_0$;

$$a_n = 2 I_0 J_n(nx) \cos(\omega n(t_2 - \theta_0 - \theta_g)) \longrightarrow (2)$$

$$b_n = 2 I_0 J_n(nx) \cos(\omega n(t_2 - \theta_0 - \theta_g)) \longrightarrow (3)$$

$n = 1, 2, 3, \ldots$

substitute above equations in i_2 (expeessinon

$$i_2\,(\text{induced}) = I_0 + 2 I_0 J_1'(x') \cdot \cos(\omega n(t_2 - \theta_0 - \theta_g))$$

$$+ 2 I_0 J_2'(2x') \cdot \cos(\omega 2(t_2 - \theta_0 - \theta_g))$$

first harmonic componetnt

second harmonic component.

(or) DC term

$$\beta_i = \frac{\sin \frac{\theta_g}{2}}{\theta_g/2}$$

~~I_2 (induced) =~~

$$i_2 = 2 I_0 J_1'(x') \cdot \cos(\omega(t_2 - \theta_0 - \theta_g))$$

magnitude of i_2 will be

$$I_2(\text{induced}) = 2 I_0 J_1'(x')$$

Then the efficiency is $\eta = \dfrac{P_{out}}{P_{in}}$

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Q.No	Marks

$$P_{out} = \frac{\beta_0 x' V_2}{R_{sh}} \qquad P_{in} = \frac{\beta_0 J_n(x') V_2}{R_{sh}}$$

$$\frac{P_{out}}{P_{in}} = \frac{2x' J_n(x')}{2\pi n - \frac{\pi}{2}}$$

$$\left(\frac{P_{out}}{P_{in}}\right) = \eta = \frac{2x' J_n(x')}{2\pi n - \frac{\pi}{2}}$$

η is about 10-20% (practically)

Substitute $J_n(x') = 0.584$, $x' = 1.841$ } → in above equation

we will get $\eta = 22.78\%$ → Theoritically.

Characteristics:

1. Frequency : 4-200 GHz
2. output power : ~~30 mW~~ 1-2.5 mW
3. Theoritical efficiency (η) : 22.78%
4. practical efficiency (η) : 10-20%

Applications :

1. It is used in Radars
2. It is used in satellite communications
3. It is used in stations.

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Q.No	Marks
2	12

Q.No	Marks

Q.No	Marks

4 (a) Attenuation:

1. A large attenuation was reduced to drastical changes in the glass to transfer in to metal.
2. A large attenuation was due to "impurities present in the glass material."
3. After purification these large attenuation was reduced to "20 dB/km" in 1970.
4. After tremendous changes happening in glass material, later two scientists discovered after some modifications 20 dB/km is again reduced to "0.2 dB/km."

Bandwidth:

1. Bandwidth is due to signal dispersion in the optical fiber.
2. The no. of bits of information is transferred in a given period of time.

Attenuation as a function of wavelength:

Attenuation offered by the fiber is maximum distance that a signal can travel before getting reduced to unacceptable levels and before getting starting use of repeaters.

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Q.No	Marks

Q.No	M

$$\alpha(dB/km) = +10\log_{10}\left(\frac{P_{in}}{P_{out}}\right) \longrightarrow (1)$$

(attenuation)

$$P_{out} = P_{in} e^{-\alpha \gamma L} \longrightarrow (2)$$

Take log on both sides

$$\log(P_{out}) = \log(P_{in} e^{-\gamma L})$$

$$10\log\left(\frac{P_{out}}{P_{in}}\right) = 10\log_e(e^{-\gamma L}) \qquad \log_e e = 0.434$$

$$(0.434 \times 10)\, e^{-\gamma t} = 10\log\left(\frac{P_{out}}{P_{in}}\right)$$

$$4.34 e^{-\gamma L} = \frac{+10\log_{10}\left(\frac{P_{in}}{P_{out}}\right)}{L}$$

$$4.34(dB/km) = \alpha(dB/km)$$

In microwave attenuation mechanisms are ~~two~~ 3 types:

1. Material absorption.
2. Scattering losses — linear / non-linear
3. Fiber losses.

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Q.No	Marks
4 a	8

Q.No	Marks

Q.No	Marks

4(b) Linear scattering losses :

- → Rayleigh scattering
- → Mie scattering

Linear:- changing path of the light

a) Rayleigh scattering:

1. Inhomogeneties present in the wave "uniformly in all directions".
2. Inhomogeneties due to Refractive index changes.

$$\alpha_{scatt} = \frac{8\pi^3}{3\lambda^4} n^8 p^2 \beta_c K T_F$$

α_{scatt} = Rayleigh scattering coefficient

λ = wavelength

n = refractive index

β_c = isothermal compressibility

K = Boltzman constant

T_F = Fictive temperature

ρ = density.

n_1^2

35.00

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Q.No	Marks	Q.No	Marks	Q.No	Marks

b) Mie scattering:

~~1. Field :~~

1. Fiber imperfections in core-cladding interface
2. changing the refractive index, core-cladding diameter.
3. Diameter fluctuations
4. Bubbles and strains.

In homogeneties present in the coare spreading only in "forward direction". Then this type of scattering is known as Mie scattering.

It causes following factors.

1. Fiber imperfections are removed by manufacturing of glass materials.
2. Coating of glass may leads to decrease in impurities.
3. changing (or) Increasing the refractive index (or) core-cladding variations.

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Q.No	Marks
Q6	5

Q.No	Marks

Q.No	Marks

5(a) **Fiber connectors :**

1. Fiber connectors are removable joints (or) temporarily joint connectors.
These are not permanent joint connects.

2. There are different types of connectors.

- connectors
  - Butt-joint
    - straight sleeve
    - Tapped sleeve
  - Expanded beam connectors.

3. connectors are of two types
1) Butt-joint connector
2) expanded beam connectors.

1. Butt-joint Connector :

These are used in attaching metals like rods, connecting with an external metals like welding.

Again Butt-joints are two types:
1. straight sleeve
2. Tapped sleeve

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Q.No	Marks

Q.No	M

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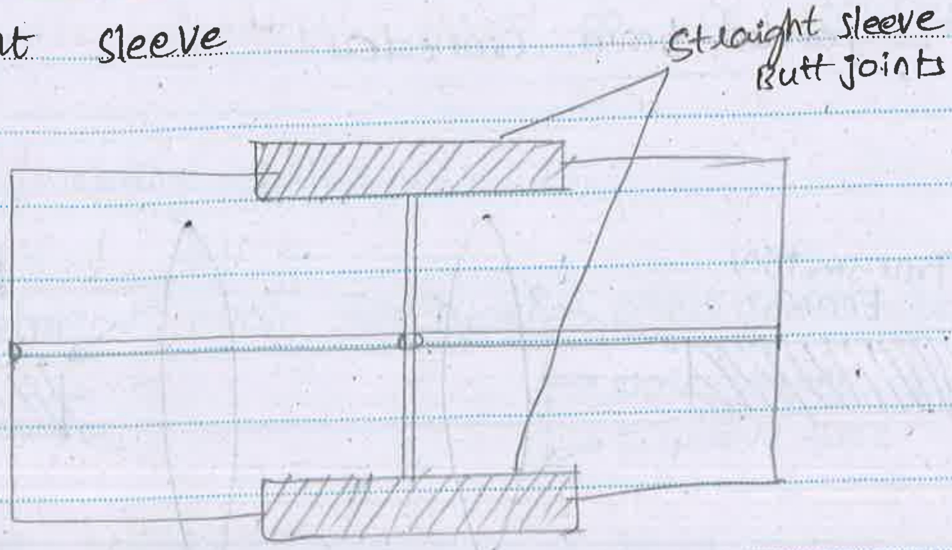
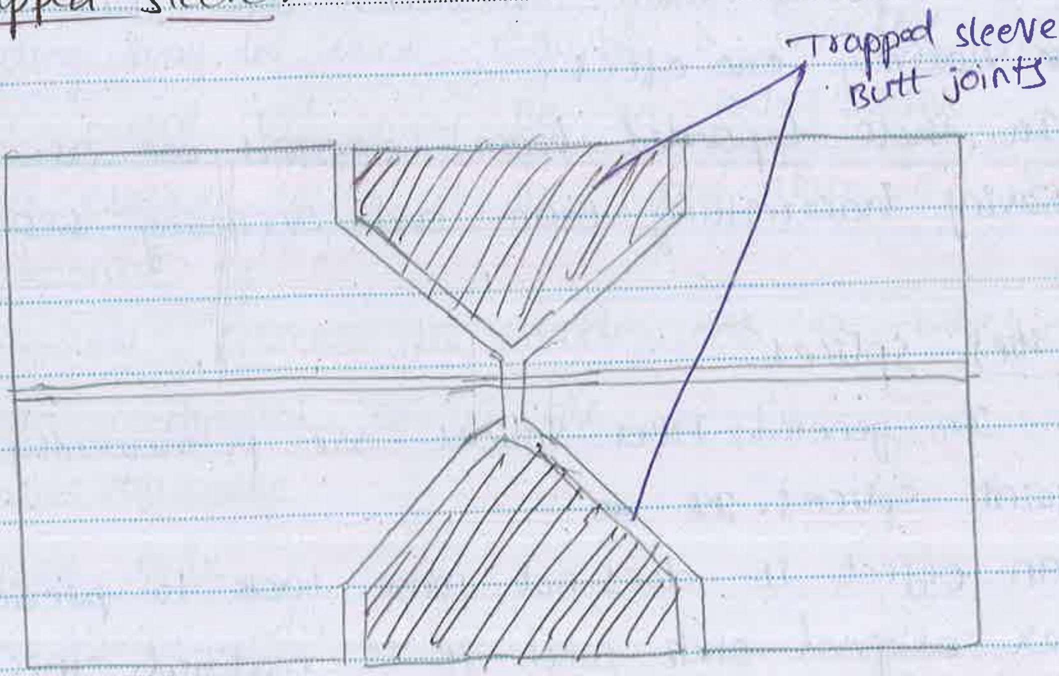
a) straight Sleeve



b) Trapped sleeve:



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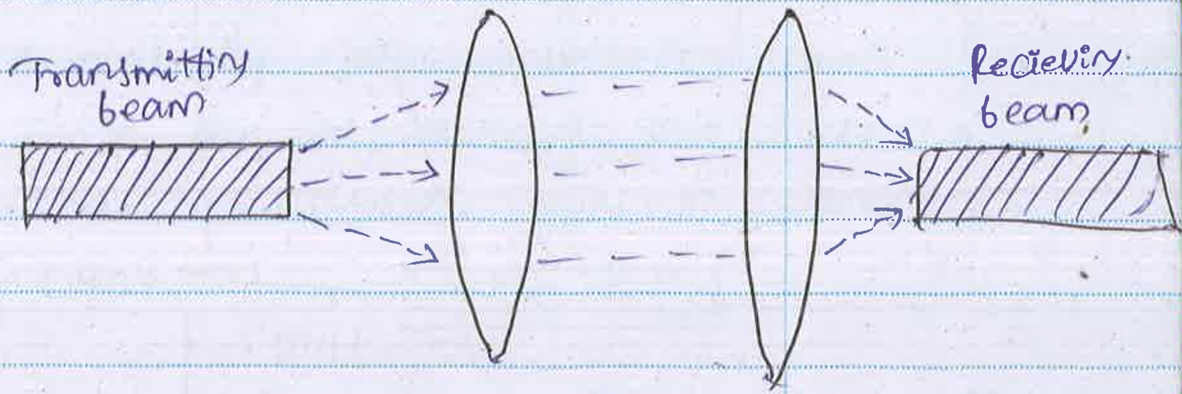
Q.No	Marks

Q.No	Marks

Q.No	Marks

2) Expanded beam connectors:



Here Expanded beam connectors are joint a relatively one after.
In these Expanded beam connecters we are having transmitting beam and recieving beam.

5(b) Fiber splices:

In general, Fiber splices are permanently joint splices.
An object it does not come back to previous or original state when it is modified. This is known as splices.

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Q.No	Marks
5a	6

Q.No	Marks

Q.No

splices are differents based on use requirenment follows:

1. fusion/welding splice
2. Mechanical splice

In mechanical again ~~two~~ types → precision ~~to~~tube
→ loose tube
→ v-groove tube

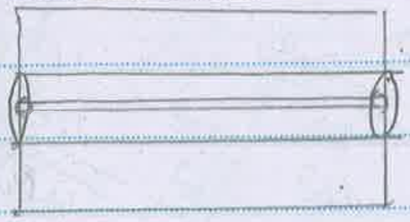
1. Welding splice:

→ Welding splices are permanently joined splice.
→ welding may be done through a metal (rods)
→ This metal rod may be in solid form
After placing splice it melts and form into solid state.

2. Mechanical splice:

→ Mechanical splices are made with a tubes
Again mechanical splices are
a) precision tube
b) loose tube
c) v- groove tube

a) precision tube:



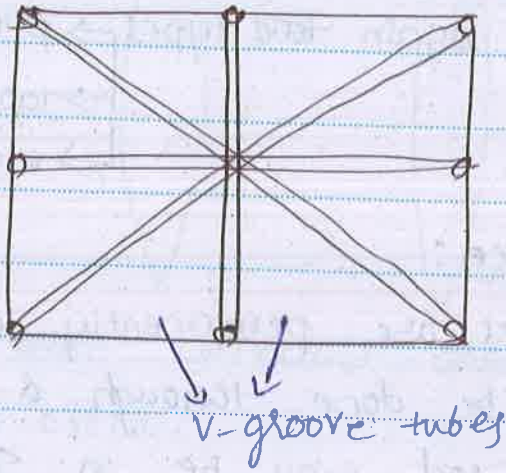
Q.No	Marks

Q.No	Marks

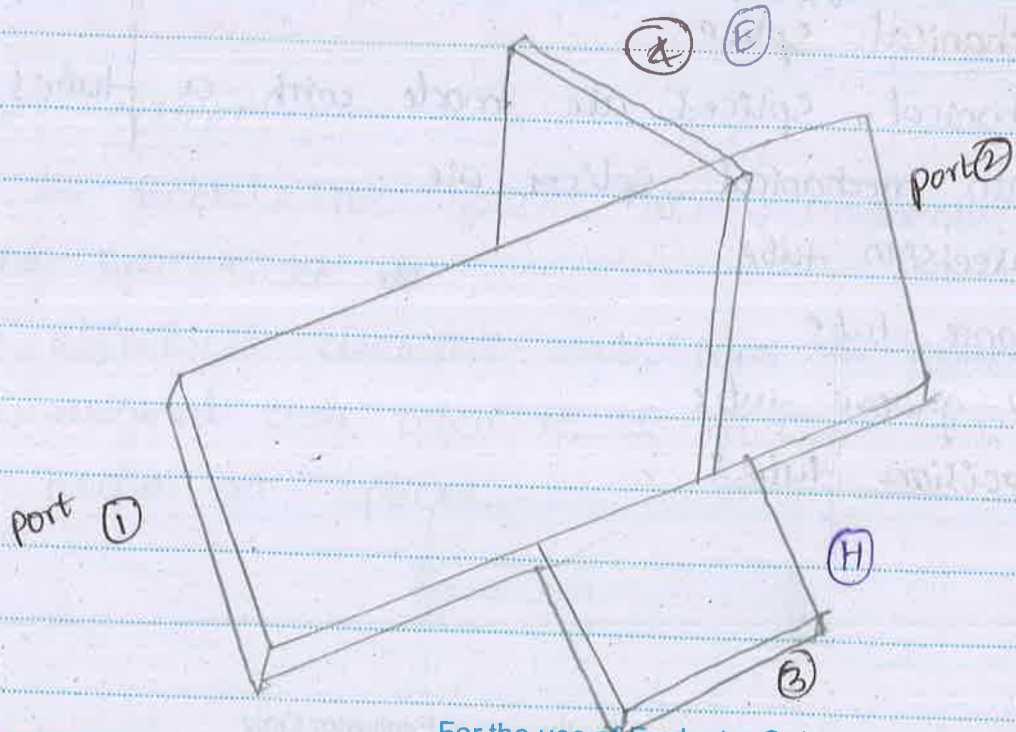
Q.No	Marks

b) loose tube

c) V-groove tubes



7(a) ~~E-H~~ Hybrid junction:



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Q.No	Marks
5b	4

Q.No	Marks

Q.No

Construction :-

Consider a two port waveguide, cut on the top wall broader dimension then add another wave guide on top wall. Again cut on the narrow dimension add another waveguide to the narrow dimension.

Working:

→ It is a 4-port device

→ when input is given at port ③ it equally divides port ①, and port ②, doesn't enter into port ④ because "symmetry mismatch". b/w ③ & ④

→ when input is given at port ④ it equall divides port ①, port ②. it doesn't enter into port ③ because "symmetry mismatch" between port ③, ④.

→ Therefore, port ③ and ④ are "isolated ports."
Because there is no communication between ③ & ④

Derivation for S-matrix

1. Apply square matrix of order n×n 4×4

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}$$

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Q.No	Marks

Q.No	Marks

Q.No	Marks

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2. From the working principle $S_{31} = S_{32}$ (H-plane)

$S_{41} = -S_{42}$ (E-plane)

$S_{43} = S_{34} = 0$ (E-H)

~~$S_{11} = S_{22} = S_{33} = S_{44} = 0$~~

$S_{33} = S_{44} = 0$

3. Apply Symmetry property.

$S_{12} = S_{21}$ $S_{14} = S_{41}$

$S_{13} = S_{31}$ $S_{24} = S_{42}$

$\Downarrow$

$S_{23} = S_{32}$

$S_{43} = S_{34} = 0$

4. Apply symmetry property results in [S]-matrix

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

5. Apply unitary matrix

$$[S_{ij}][S_{ij}]^* = [I]$$

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Q.No	Marks

Q.No

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

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

$R_1C_1 \Rightarrow |S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 + |S_{14}|^2 = 1 \longrightarrow (1)$

$R_2C_2 \Rightarrow |S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2 + |S_{14}|^2 = 1 \longrightarrow (2)$

$R_3C_3 \Rightarrow |S_{13}|^2 + |S_{13}|^2 = 1 \longrightarrow (3)$

$R_4C_4 \Rightarrow |S_{14}|^2 + |S_{14}|^2 = 1 \longrightarrow (4)$

$(3) \Rightarrow 2|S_{13}|^2 = 1$ $\quad$ $(4) \Rightarrow 2|S_{14}|^2 = 1$

$S_{13} = \frac{1}{\sqrt{2}}$ $\quad$ $S_{14} = \frac{1}{\sqrt{2}}$

$R_3C_4 \Rightarrow S_{13} \cdot S_{14}^* + S_{13}(-S_{14})^* = 0 \longrightarrow (5)$

For the use of Evaluator Only

Q.No	Marks	Q.No	Marks	Q.No	Marks

Solving eq ① - Eq ②

we, get $\boxed{S_{11} = S_{22}}$

Substitute all the results in [S] - matrix

perfectly mismatch

$$S_{ij} = \begin{bmatrix} 0 & 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 0 & 0 & \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 & 0 \end{bmatrix}$$

magic

symmetry mismatch

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

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Q.No	Marks
7a	6

Q.No	Marks

Q.No	M

7 (b) $P_i = 90 W$

$C = 20 dB$

$D = 35 dB$

$$C = 10\log_{10}\left(\frac{P_i}{P_f}\right)$$

$$20 = 10\log_{10}\left(\frac{90}{P_f}\right)$$

$$\log_{10}\left(\frac{90}{P_f}\right) = \frac{20}{10}$$

$$\frac{90}{P_f} = 10^2$$

$$90 = 10^2 \cdot P_f$$

$$P_f = \frac{90}{100}$$

$$\boxed{P_f = 0.9 mW}$$

$$I = C + D$$

$$I = 20 + 35$$

$$\boxed{I = 55}$$

$$D = 10\log_{10}\left(\frac{P_f}{P_b}\right)$$

$$35 = 10\log_{10}\left(\frac{0.9\times10^{-3}}{P_b}\right)$$

$$\log\left(\frac{0.9 mW}{P_b}\right) = \frac{35}{10} = 3.5$$

$$\frac{0.9 mW}{P_b} = 3162.27$$

$$P_b = \frac{0.9\times10^{-3}}{3162.27}$$

$$P_b = 2.84\times10^{-7} W$$

$$\boxed{P_b = 0.28\times10^{-6} mW}$$

$$I = 10\log_{10}\left(\frac{0.9}{0.28\times10^{-6}}\right)$$

$$\boxed{I = 65.00 dB}$$

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Q.No	Marks
7b	6.

Q.No	Marks

Q.No	Marks

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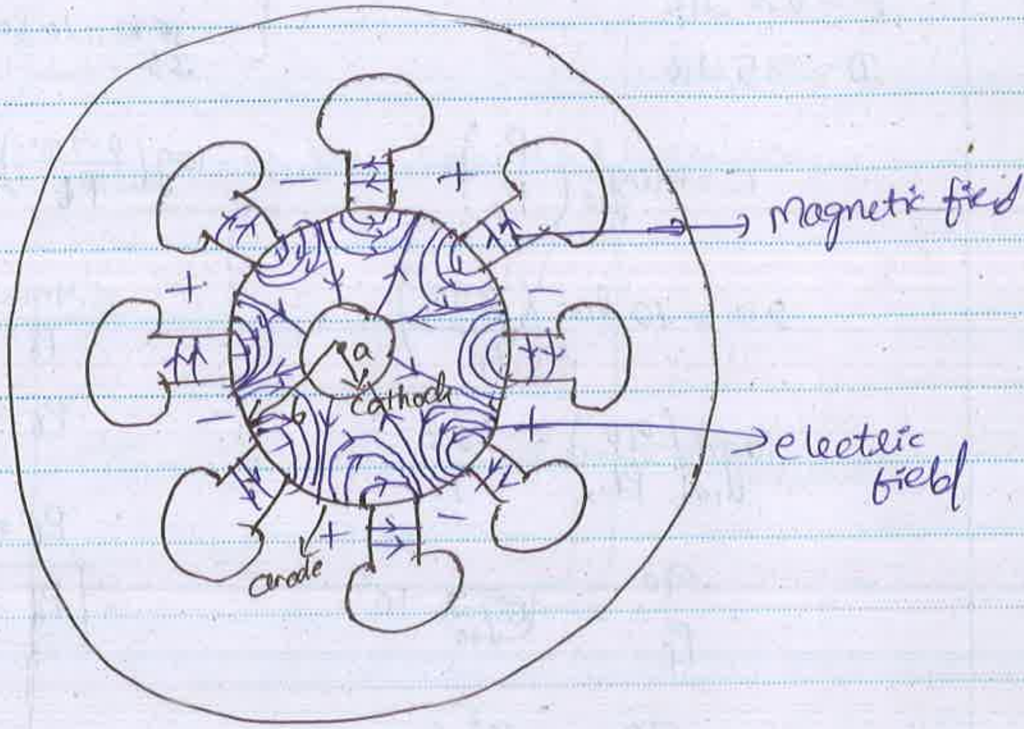
1 (a) cylindrical magnetron:



we know that cyclindrical magnetron

$$\phi = \frac{2\pi n}{N} \quad (n = 0, 1, 2, \ldots)$$

$\boxed{\phi = \pi}$ where $n = \frac{N}{2}$ $(n = 0, 1, 2 \ldots)$

~~cyclic~~ cylindrical magnetron acting as π-mode. when $n = \frac{N}{2}$

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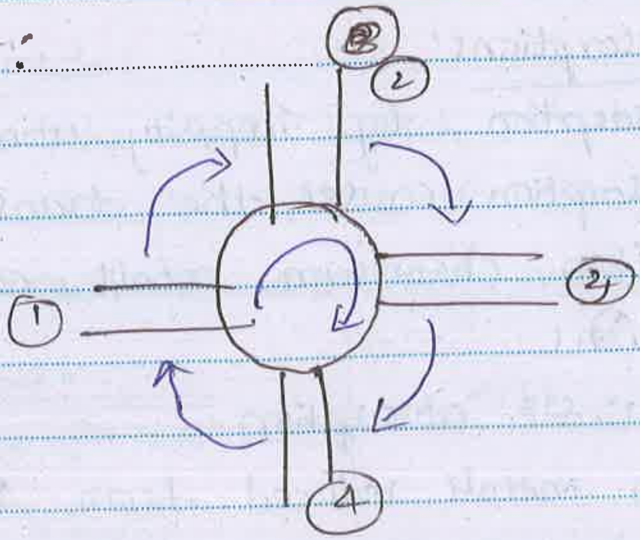
Q.No	Marks
1a	0

Q.No	Marks

Q.No	Marks

1 (b) circulator:



Circulator are of different types
circulator is rotating in clockwise direction.
The ports are connected eg adjacently one after another.

operation:

when the input is given at port①, the output should be adjacently of next port i.e port②
when input is at port② the output should be at port ③
when input is at port③ the output should be port ④

For the use of Evaluator Only

Q.No	Marks
1b	2

Q.No	Marks

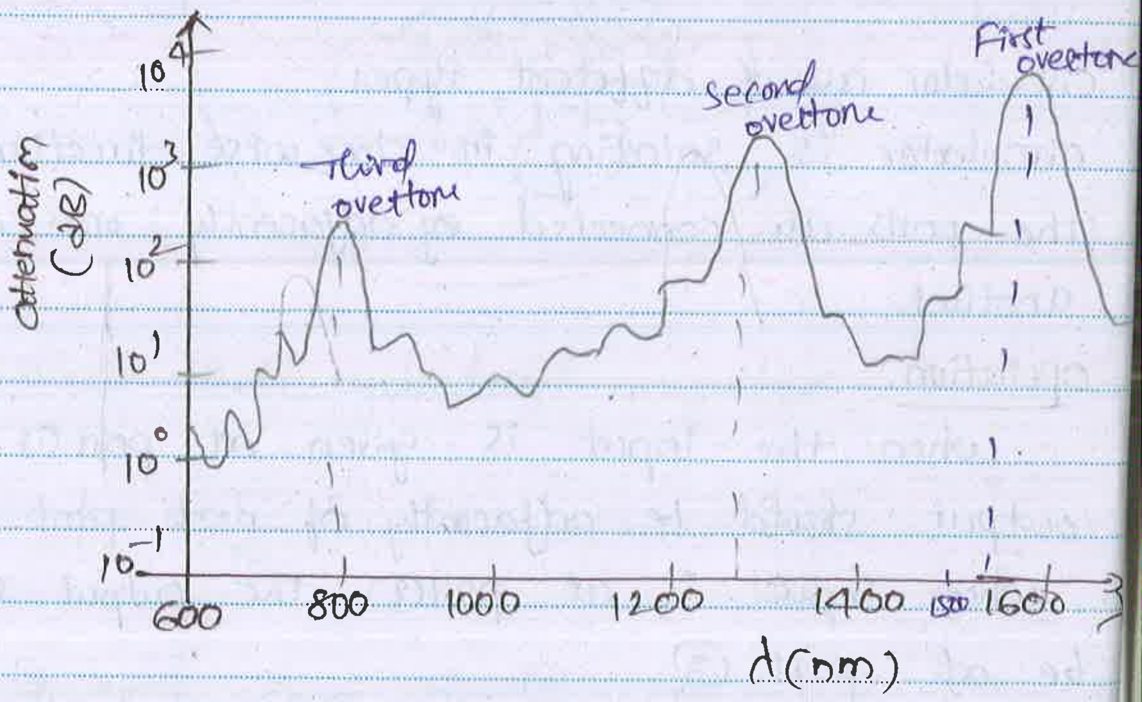
Q.No	Marks

1 (c) Extrinsic absorptions:

1. Extrinsic absorption by impurity atoms.
2. Extrinsic absorption causes the transition metals such as iron, chromium, cobalt, copper and (OH) water ions.

~~3 extr The extrinsic absorption~~

3. The transition metals reduced from 1 to 10 dB.



first window = 800 nm

Second window = 1300 nm

Third window = 1550 nm

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Q.No	Marks
1c	1

Q.No	Marks

Q.No	

1 (d) Dominant mode :

It is the mode which is having highesht cut-off wavelength or lowest cut-off frequency. This is known as Dominant mode.

$$\lambda_c = \frac{2ab}{\sqrt{(mb)^2+(na)^2}}$$

$$TE_{00} = \frac{2(0)(0)}{\sqrt{0^2+0^2}}$$

$$TE_{00} = 0$$

$$TE_{01} = \frac{2(0)(1)}{\sqrt{(mb)^2+(na)^2}}$$

$$TE_{10} = \frac{2a}{\sqrt{(na)^2}}$$

$$TM_{00} = 0$$

$$TM_{01} = \frac{2b(0)}{\sqrt{m(0)^2+n^2}}$$

TM_{10} = not possible

TM_{11} = exist

TE_{10} = Dominant mode

TM_{11} = Dominant mode

why because of TE_{10} and TM_{11} having highest cutoff wavelength (or) lowest cut-off frequency.

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Q.No	Marks
1b	2

Q.No	Marks

Q.No	Marks

1 (e) **Requirements of a optical souce:**

1. Low cost.
2. Less reliable.
3. Smaller in size and weight is low.
4. Less sensitivity.
5. More gain is suited.
6. Coupling efficieny is very low.
7. Band width is high.
8. quantum efficiency is about 60%.

1 (f) The relation between cut-off wavelength (λ) and V-number.

$$V = \frac{2\pi a}{\lambda}(NA)$$

$$V = \sqrt{U^2 + \omega^2} \longrightarrow (1)$$

Where V = V-number (or) normalised frequen

U = Radial feequeny

$$U = a\sqrt{n_1^2 K^2 - \beta^2} \longrightarrow (2)$$

$$V = a\sqrt{\beta^2 - n_2^2 K^2} \longrightarrow (3)$$

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Q.No	Marks
1e	1

Q.No	Marks
1f	✓

Q.No

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Substitute eq②,③ in eq①

$$V = \sqrt{a^2(n_1^2k^2 - \beta^2) + a^2(\beta^2 - n_2^2 k^2)}$$

$$V = \sqrt{a^2(n_1^2k^2 - \beta^2 + \beta^2 - n_2^2 k^2)}$$

$$V = a\sqrt{n_1^2k^2 - n_2^2k^2}$$

$$V = \frac{2\pi a}{\lambda}\sqrt{n_1^2 - n_2^2}$$

$$V = \frac{2\pi a}{\lambda}(\sqrt{n_1^2 - n_2^2})$$

** $$V = \frac{2\pi a}{\lambda}(NA)$$

NA = Numerical aperture

$NA = \sqrt{n_1^2 - n_2^2}$

$$V = \frac{2\pi a}{\lambda(\mu m)}(NA)$$

Here λ is measured in μm

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

Substitute eq ②, ③ in eq ①

$$V = \sqrt{a^2(n_1^2 K^2 - \beta^2) + a^2(\beta^2 - n_2^2 K^2)}$$

$$V = \sqrt{a^2(n_1^2 K^2 - \beta^2 + \beta^2 - n_2^2 K^2)}$$

$$V = a\sqrt{n_1^2 K^2 - n_2^2 K^2}$$

$$V = \frac{2\pi a}{\lambda}\sqrt{n_1^2 - n_2^2}$$

$$V = \frac{2\pi a}{\lambda}\left(\sqrt{n_1^2 - n_2^2}\right)$$

** $$\boxed{V = \frac{2\pi a}{\lambda}(NA)}$$

NA = Numerical aperture

$NA = \sqrt{n_1^2 - n_2^2}$

$$\boxed{V = \frac{2\pi a}{\lambda(\mu m)}(NA)}$$

Here λ is measured in μm

(ESTD-1995)

1 (g)

TWT	Reflex Klystron
1. Travelling wave tube	1. Reflex Klystron
2. It is an amplifier	2. It is an oscillator
	3. Here velocity and current modulation occur
3. frequency : 3 GHZ	4. frequency : 4-200 GHz
4. power : 10 KW	5. power : 1 – 2.5 mW
5. Efficiency η : 20–40%	6. Theoritical η : ~~10–20%~~ 22
6. Bandwidth : 0.8 dB	7. practical η : 10 – 20%
	8. Used in radars
	9. $\eta = \frac{2X'J_1(X)}{2\pi n - \frac{\pi}{2}}$

6 (a) λ_g = guided wavelength

λ_0 = free space wavelength

λ_c = cut-off wavelength

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda_0^2} - \frac{1}{\lambda_c^2}$$

we know that

$$\lambda_g = \frac{\lambda_c}{\sqrt{1-\left(\frac{\lambda_c}{\lambda_0}\right)^2}}$$

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Q.No	Marks
19	✓

Q.No	Marks

Q.No	M

$$\sqrt{1-\left(\frac{\lambda_c}{\lambda_0}\right)^2}\cdot \lambda_g = \lambda_c$$

S.O.B

$$\lambda_g^2 = \frac{\lambda_c^2}{1-\left(\frac{\lambda_c}{\lambda_0}\right)^2}$$

$$\lambda_g^2 = \frac{\lambda_c^2}{\frac{\lambda_0^2-\lambda_c^2}{\lambda_0^2}} = \lambda_c^2 \times \frac{\lambda_0^2}{\lambda_0^2-\lambda_c^2}$$

$$\lambda_g^2 = \lambda_c^2 \times \frac{\lambda_0^2}{\lambda_0^2\left(1-\frac{\lambda_c^2}{\lambda_0^2}\right)} = \lambda_c^2 \times \frac{1}{\frac{\lambda_0^2-\lambda_c^2}{\lambda_0^2}} = \lambda_c^2 \times \frac{\lambda_0^2}{\lambda_0^2-\lambda_c^2}$$

$$\boxed{\frac{1}{\lambda_g^2} = \frac{1}{\lambda_0^2} - \frac{1}{\lambda_c^2}}$$

6 (b)

$a = 5\text{cm}$

$b = 2\text{cm}$

$f = 9\text{GHz}$

$f = \frac{c}{\lambda}$

$\lambda_0 = \frac{c}{f} = \frac{3\times10^{10}}{9\times10^9} = 3.33$

$$\lambda_c = \frac{2ab}{\sqrt{(mb)^2+(na)^2}}$$

TM_{11}

$m=1, n=1$

$$\lambda_c = \frac{2(5)(2)}{\sqrt{2^2+5^2}}$$

$\lambda_c = 3.71$

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Q.No	Marks
6a	6

Q.No	Marks

Q.No	Marks

Wave impedance in TM

$$Z_{TM} = \frac{c}{\sqrt{1-\left(\frac{\lambda_c}{\lambda_0}\right)^2}}$$

$$Z_{TM} = \frac{3\times10^{10}}{\sqrt{1-\left(\frac{3.71}{3.33}\right)^2}}$$

$$Z_{TM} = 166.67$$

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Q.No	Marks
66	5

Q.No	Marks

Q.No	M