Question # 1 (18Marks)

1. Identify the high frequency limitations of conventional tubes and how these limitations are improved by microwaves tubes (4Marks).

- The conventional tubes such as triode, tetrodes, and pentodes can be used as amplifiers and oscillators more efficiently. But these conventional tubes cannot used as amplifier or oscillator at high frequency (>1000MHZ) because at higher frequencies output drops off

The factors of contributing of output at UHF are

1. Circuit resistance

a) Inter electrode capacitance

b) Lead inductance

2. Transit time effects

3. Cathode emission plate heat dissipation area

4. Power loss due to skin effect, radiation and dielectric loss

5. Gain band width product.

2. What should be the spacing between the buncher and the catcher cavities in order to achieve a max degree of bunching, with analysis? Give the drawbacks of klystron amplifiers. (7Marks).

(4)

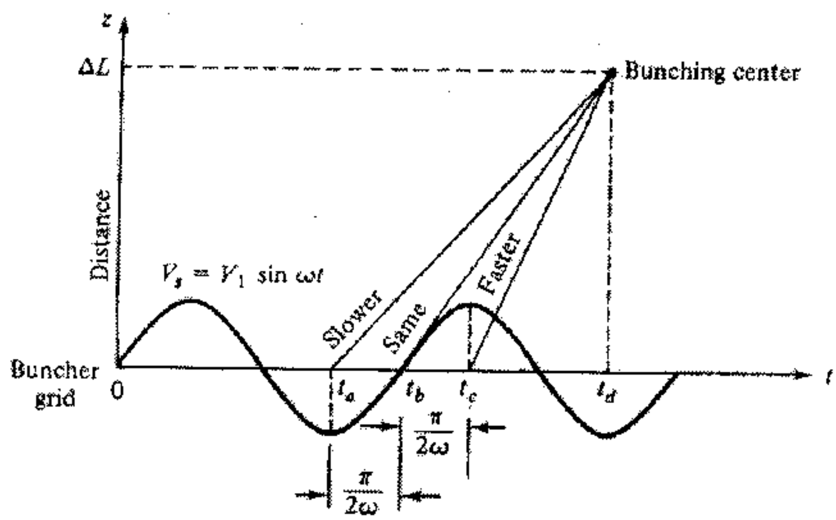


Figure 9-2-8 Bunching distance.

The distance from the buncher grid to the location of dense electron bunching for the electron at t_b is

$$\Delta L = v_0(t_d - t_b)$$

Similarly, the distances for the electrons at *ta* and *tc*:

$$\Delta L = v_{min}(t_d - t_a) = v_{min}\left(t_d - t_b + \frac{\pi}{2\omega}\right)$$

$$\Delta L = v_{max}(t_d - t_c) = v_{max}\left(t_d - t_b - \frac{\pi}{2\omega}\right)$$

From previous Eqs: the minimum and maximum velocities are:

$$v_{min} = v_0\left(1 - \frac{\beta_i V_1}{2V_0}\right) \quad v_{max} = v_0\left(1 + \frac{\beta_i V_1}{2V_0}\right)$$

By Substituting. The distance

$$\Delta L = v_0(t_d - t_b) + \left[v_0\frac{\pi}{2\omega} - v_0\frac{\beta_i V_1}{2V_0}(t_d - t_b) - v_0\frac{\beta_i V_1}{2V_0}\frac{\pi}{2\omega}\right]$$

and

$$\Delta L = v_0(t_d - t_b) + \left[-v_0\frac{\pi}{2\omega} + v_0\frac{\beta_i V_1}{2V_0}(t_d - t_b) + v_0\frac{\beta_i V_1}{2V_0}\frac{\pi}{2\omega}\right]$$

The necessary condition for those electrons at *ta* , *tb*, and *tc* to meet at the same distance ΔL is:

$$v_0\frac{\pi}{2\omega} - v_0\frac{\beta_i V_1}{2V_0}(t_d - t_b) - v_0\frac{\beta_i V_1}{2V_0}\frac{\pi}{2\omega} = 0$$

$$-v_0\frac{\pi}{2\omega} + v_0\frac{\beta_i V_1}{2V_0}(t_d - t_b) + v_0\frac{\beta_i V_1}{2V_0}\frac{\pi}{2\omega} = 0$$

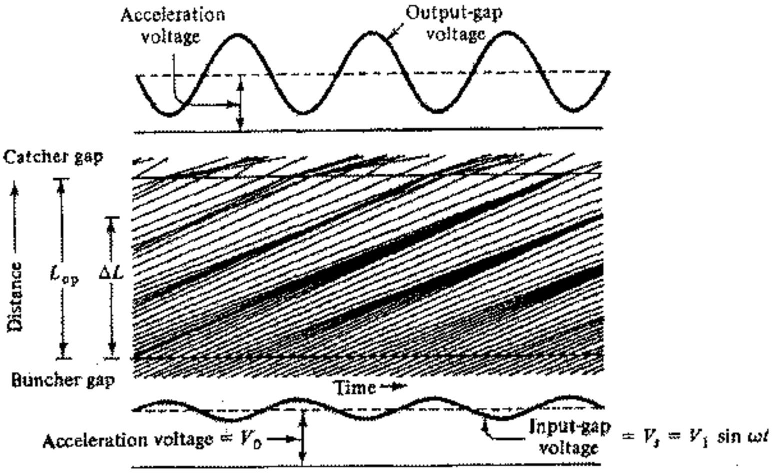
$$t_d - t_b \approx \frac{\pi V_0}{\omega\beta_i V_1}$$

$$\Delta L = v_0\frac{\pi V_0}{\omega\beta_i V_1}$$

(**) **It should be noted that the mutual repulsion of the space charge is neglected, but the qualitative results are similar to the preceding representation when the effects of repulsion are included. Since the drift region is field free, the transit time for an electron to travel a distance of L as shown in Fig.**

$$T = t_2 - t_1 = \frac{L}{v(t_1)} = T_0\left[1 - \frac{\beta_i V_1}{2V_0}\sin\left(\omega t_1 - \frac{\theta_g}{2}\right)\right]$$

where the binomial expansion of $(1 + x)^{-1}$ for $|x| \ll 1$ has been replaced and $T_o = L/v_o$ is the de transit time. In terms of radians the preceding expression can be written



$$\theta_0 = \frac{\omega L}{v_0} = 2\pi N$$

is the de transit angle between cavities, N is the number of electron transit cycles in the drift space, and X is defined as the *bunching parameter* of a klystron

- **The drawbacks of klystron amplifiers.** (2)

1. As the oscillator frequency changes then resonator frequency also changes and the feedback path phase shift must be readjusted for a positive feedback.

2. The multicavity klystron amplifiers suffer from the noise caused because bunching is never complete and electrons arrive at random at catcher cavity. Hence it is not used in receivers

Question # 2 (18 Marks)

1. Explain the operating principle of reflex klystron, clarify the flowing, Why do different modes of operation exist for a reflex and How does bunching occur in a reflex klystron? What are the assumptions for calculation of RF power in Reflex Klystron? (6Marks).

- It works on the principle of velocity modulation and current modulation. The operating principle of reflex klystron is clearly explained from the following figure (explain briefly)

Why do different modes of operation exist for a reflex?

- There are several combinations of repeller voltage and anode voltage that provide favourable conditions for bunching. Accordingly there may exist several modes of operation, expressed by N + ¾ where N is an integer.

How does bunching occur in a reflex klystron?

A reference electron passing the gap when the gap voltage is zero travels with no change in velocity. An electron leaving the gap earlier during slightly positive voltage would travel further into repeller space and hence would take longer time then the reference e to return to the gap. An electron leaving the gap later will face slightly negative voltage & gets retarded. So it returns back after a shorter travel in the repeller space. Thus all the electrons would arrive back to the gap in bunches. Bunching around reference electron takes place once per cycle of RF oscillations.

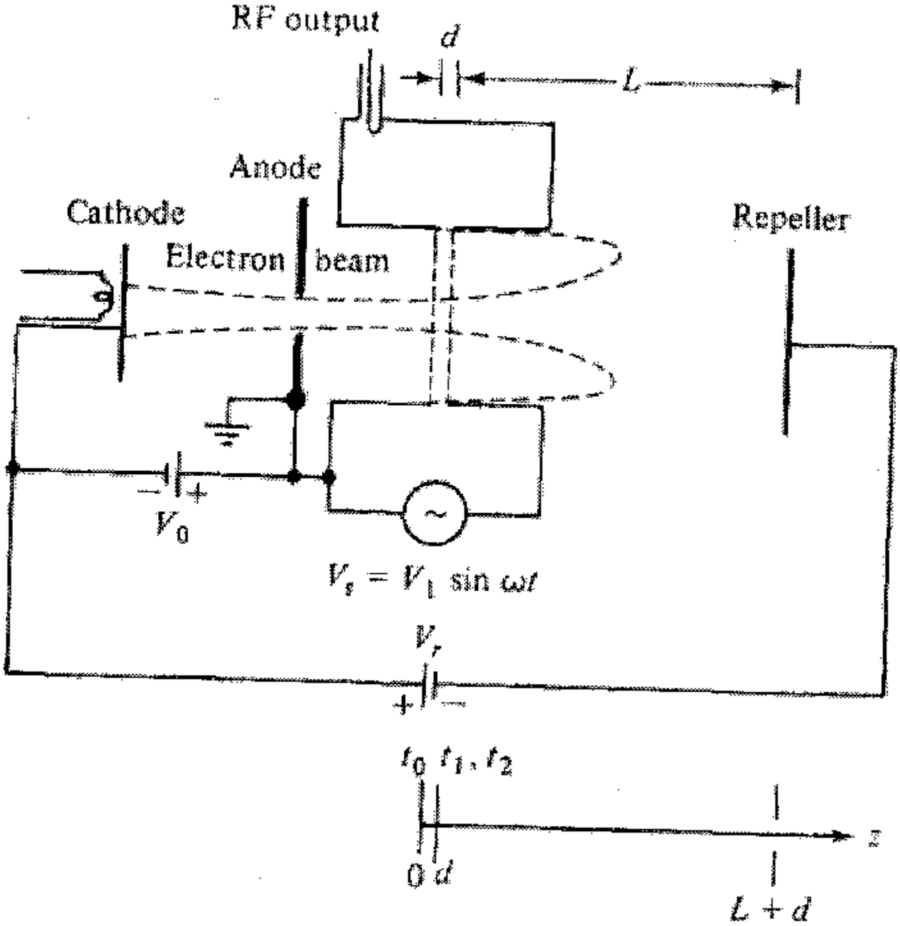
-What are the assumptions for calculation of RF power in Reflex Klystron?

i) Cavity grids and repeller is plane parallel and very large in extent.

ii) No RF field is excited in repeller space

iii) Electrons are not intercepted by the cavity anode grid.

iv) No debunching takes place in repeller space.



t_0 = time for electron entering cavity gap at $z = 0$
t_1 = time for same electron leaving cavity gap at $z = d$
t_2 = time for same electron returned by retarding field $z = d$ and collected on walls of cavity

2. Drive an expression for the round trip transit time in the repeller region "T′" of the reflex klystron cavity. (<u>6Marks</u>).

- The analysis of a reflex klystron is similar to that of a two-cavity klystron. For simplicity, the effect of space-charge forces on the electron motion will again be neglected. The electron entering the cavity gap from the cathode at $z = 0$ and time *to* is assumed to have uniform velocity

$$v_0 = 0.593 \times 10^6 \sqrt{V_0}$$

The same electron leaves the cavity gap at $z = d$ at time *ti* with velocity

$$v(t_1) = v_0\left[1 + \frac{\beta_1 V_1}{2V_0} \sin\left(\omega t_1 - \frac{\theta_g}{2}\right)\right]$$

The same electron is forced back to the cavity z = d and time tz by the retarding electric field E, which is given by

$$E = \frac{V_r + V_0 + V_1 \sin(\omega t)}{L}$$

This retarding field E is assumed to be constant in the z direction. The force equation for one electron in the repeller region is

$$m \frac{d^2 z}{dt^2} = -eE = -e \frac{V_r + V_0}{L}$$

where $E = -\Delta V$ is used in the z direction only, V_r is the magnitude of the repeller voltage, and $|V \sin wt| \ll (V_r + V_0)$ is assumed. Integration of Eq. twice yields

$$\frac{dz}{dt} = \frac{-e(V_r + V_0)}{mL} \int_{t1}^{t} dt = \frac{-e(V_r + V_0)}{mL}(t - t_1) + K_1$$

at $t = t_1$, $dz/dt = v(t_1) = K_1$; then

$$z = \frac{-e(V_r + V_0)}{mL} \int_{t_1}^{t} (t - t_1)\, dt + v(t_1) \int_{t_1}^{t} dt$$

$$z = \frac{-e(V_r + V_0)}{2mL}(t - t_1)^2 + v(t_1)(t - t_1) + K_2$$

at $t = t_1$, $z = d = K_2$; then

$$z = \frac{-e(V_r + V_0)}{2mL}(t - t_1)^2 + v(t_1)(t - t_1) + d$$

On the assumption that the electron leaves the cavity gap at $z = d$ and time t_1 with a velocity of $v(t_1)$ and returns to the gap at $z = d$ and time t_2, then, at $t = t_2$, $z = d$,

$$0 = \frac{-e(V_r + V_0)}{2mL}(t_2 - t_1)^2 + v(t_1)(t_2 - t_1)$$

On the assumption that the electron leaves the cavity gap at $z = d$ and time t_1 with a velocity of $v(t_1)$ and returns to the gap at $z = d$ and time t_2, then, at $t = t_2$, $z = d$,

$$0 = \frac{-e(V_r + V_0)}{2mL}(t_2 - t_1)^2 + v(t_1)(t_2 - t_1)$$

The round-trip transit time in the repeller region is given by

$$T' = t_2 - t_1 = \frac{2mL}{e(V_r + V_0)} v(t_1) = T_0' \left[1 + \frac{\beta_i V_1}{2V_0} \sin\left(\omega t_1 - \frac{\theta_g}{2}\right)\right] \qquad (9\text{-}4\text{-}7)$$

where

$$T_0' = \frac{2mLv_0}{e(V_r + V_0)} \qquad (9\text{-}4\text{-}8)$$

is the round-trip dc transit time of the center-of-the-bunch electron.

Multiplication of Eq. (9-4-7) through by a radian frequency results in

$$\omega(t_2 - t_1) = \theta_0' + X' \sin\left(\omega t_1 - \frac{\theta_g}{2}\right) \qquad (9\text{-}4\text{-}9)$$

where

$$\theta_0' = \omega T_0' \qquad (9\text{-}4\text{-}10)$$

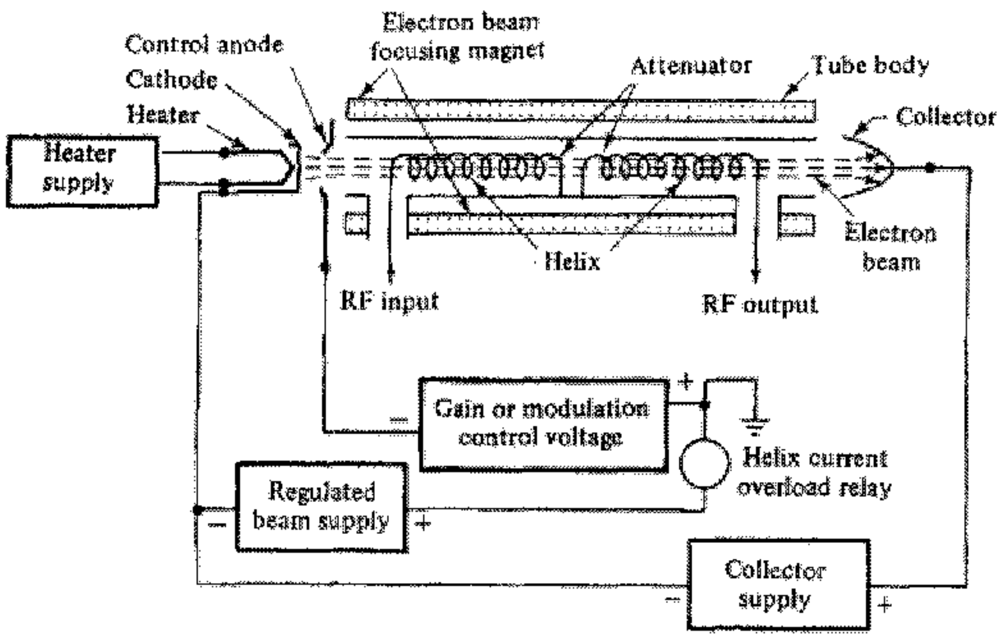
is the round-trip dc transit angle of the center-of-the-bunch electron and

$$X' \equiv \frac{\beta_i V_1}{2V_0} \theta_0' \qquad (9\text{-}4\text{-}11)$$

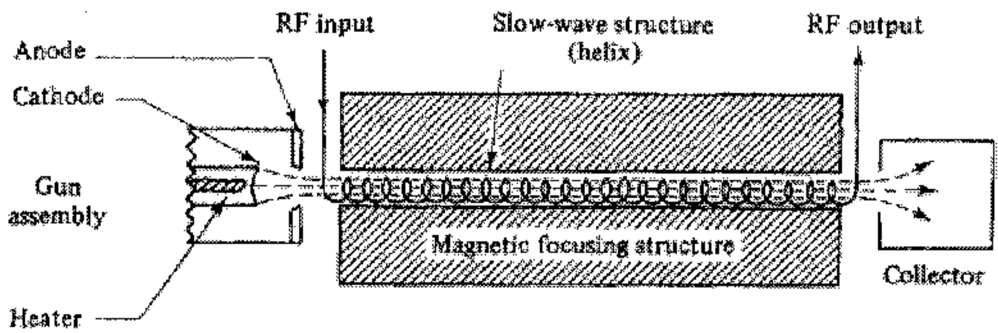
Question # 3 (17 Marks)

1. Sketch the TWT diagram, clarify the flowing, what is the purpose of slow wave structures used in TWT amplifiers? How are spurious oscillations generated in TWT amplifier? State the method to suppress it. (<u>7Marks</u>).

Slow wave structures are special circuits that are used in microwave tubes to reduce wave velocity in a certain direction so that the electron beam and the signal wave can interact. In TWT, since the beam can be accelerated only to velocities that are about a fraction of the velocity of light, slow wave structures are used.
In a TWT, adjacent turns of the helix are so close to each other and hence oscillations are likely to occur. To prevent these spurious signals some form of attenuator is placed near the input end of the tube which absorb the oscillations.



(a)

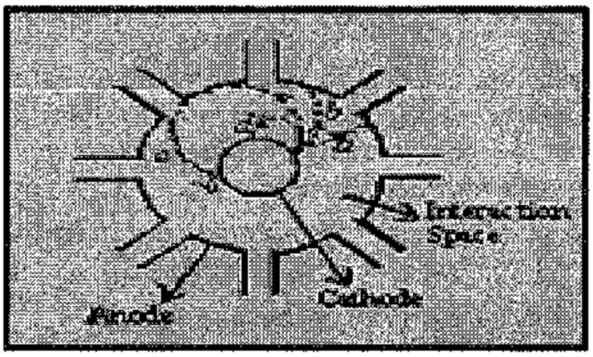


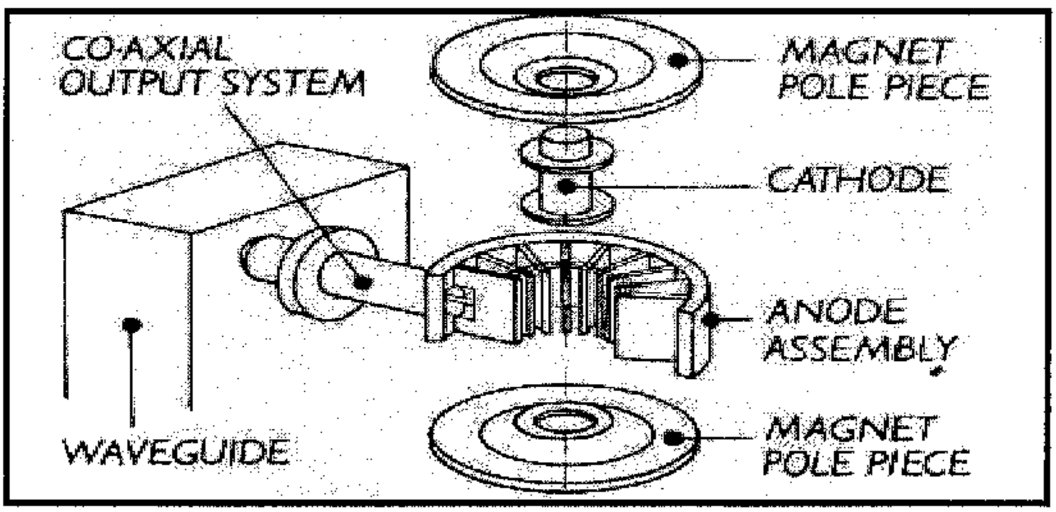
Question # 4 (17 Marks)

1. **Explain the principle operation of the magnetron cavity, (Sketch the diagram), what is the magnetron operation mode and How ensure to operate in it? (<u>6Marks</u>).**

Working principle:

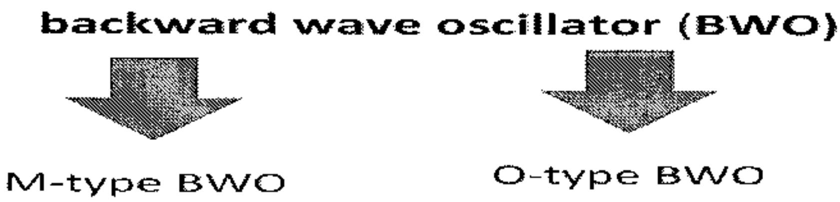
- Magnetron is a cross field device as the electric field between the anode and the cathode is radial whereas the magnetic field produced by a permanent magnet is axial.
- A high dc potential can be applied between the cathode and anode which produces the radial electric field.
- Depending on the relative strengths of the electric and magnetic fields, the electrons emitted from the cathode and moving towards the anode will traverse through the interaction space.
- In the absence of magnetic field ($B = 0$), the electron travel straight from the cathode to the anode due to the radial electric field force acting on it as given by the path 'a' in the following figure.
- If the magnetic field strength is increased slightly, the lateral force bending the path of the electron as given by the path '*b*' in the following figure.
- The radius of the path is given by, if the strength of the magnetic field is made sufficiently high , then the electrons can be prevented from reaching the anode as indicated path '*c*' in figure shown below.
- The magnetic field required to return electrons back to the cathode just grazing the surface of the anode is called the *critical magnetic field* (B_c) *or the cut-off magnetic field.*
- If the magnetic field is larger than the critical field ($B > B_c$), the electron experiences a greater rotational force and may return back to the cathode quite faster.
- The various motion of electrons in the presence of different magnitudes of magnetic field can be viewed in the following figures,



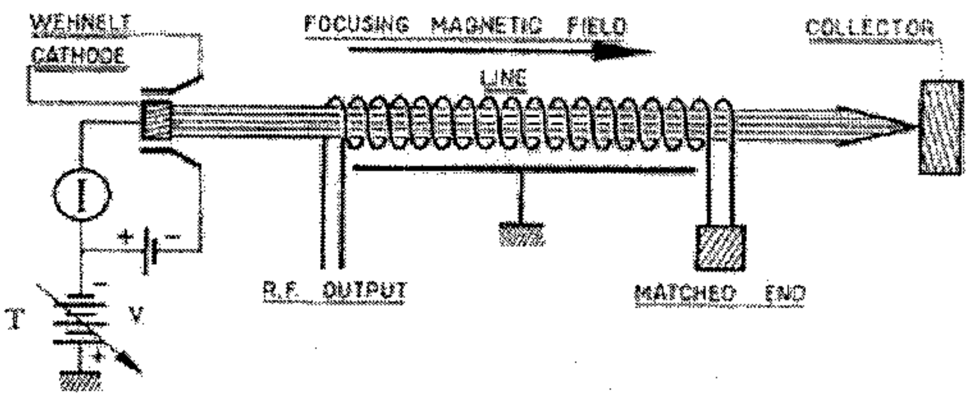


It is normal to keep operation of in the π -mode for **good frequency stability** also magnetron operating in the π mode has **greater power**.
There are two main methods to keep magnetron operation in the π – mode :
1-Strapping (for Wavelength>3 cm)
2-*Rising sun method (*For Wavelength<3 cm)

2. **List the types of backward wave oscillator "BWO", then explain the principle operation of any one of them (Sketch the diagram). (<u>6Marks</u>).**



• A **backward wave oscillator** (BWO), also called **carcinotron** (trade name) or **backward wave tube**, is a vacuum tube that is used to generate microwaves up to the terahertz range.
• It belongs to the traveling-wave tube family.
• It is an oscillator with a wide electronic tuning range
An electron gun generates an electron beam that is interacting with a slow-wave structure.
• It sustains the oscillations by propagating a traveling wave backwards against the beam
• The generated electromagnetic wave power has its group velocity directed oppositely to the direction of motion of the electrons.
• The output power is coupled out near the electron gun.



O-type backward wave oscillator (O-carcinotron) with bifilar helix as delay line

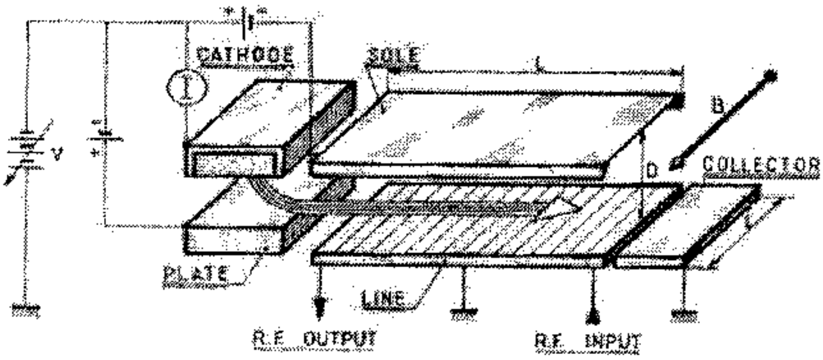


Fig. M-type backward wave oscillator (M-carcinotron) with planar periodic delay line

• The **M-type carcinotron**, or **M-type backward wave oscillator**, uses crossed static electric field E and magnetic field B, similar to the magnetron, for focussing an electron sheet beam drifting perpendicularly to E and B, along a slow-wave circuit, with a velocity E/B.
• Strong interaction occurs when the phase velocity of one space harmonic of the wave is equal to the electron velocity.
• Both Ez and Ey components of the RF field are involved in the interaction (Ey parallel to the static E field).
• Electrons which are in a decelerating Ez electric field of the slow-wave, lose the kinetic energy they have in the static electric field E and reach the circuit.
• The sole electrode is more negative than the cathode, in order to avoid collecting those electrons having gained energy while interacting with the slow-wave space harmonic.

Question # 5 (20Marks)

1. **Describe the operation of GUNN diode, and show how tuning it. (4Marks).**

Gunn diodes are also known as transferred electron devices, TED, are widely used in microwave RF applications for frequencies between 1 and 100 GHz.
The Gunn diode is most commonly used for generating microwave RF signals - these circuits may also be called a transferred electron oscillator or TEO. The Gunn diode may also be used for an amplifier in what may be known as a transferred electron amplifier or TEA.
As Gunn diodes are easy to use, they form a relatively low cost method for generating microwave RF signals.
Gunn diode basics
The Gunn diode is a unique component - even though it is called a diode, it does not contain a PN diode junction. The Gunn diode or transferred electron device can be termed a diode because it does have two electrodes. It depends upon the bulk material properties rather than that of a PN junction. The Gunn diode operation depends on the fact that it has a voltage controlled negative resistance.
A discrete Gunn diode with the active layer mounted onto a heat sink for efficient heat transfer
The most common method of manufacturing a Gunn diode is to grow and epitaxial layer on a degenerate n+ substrate. The active region is between a few microns and a few hundred micron thick. This active layer has a doping level between $10^{14}cm^{-3}$ and

$10^{16}cm^{-3}$ - this is considerably less than that used for the top and bottom areas of the device. The thickness will vary according to the frequency required.

The top n+ layer can be deposited epitaxially or doped using ion implantation. Both top and bottom areas of the device are heavily doped to give n+ material. This provides the required high conductivity areas that are needed for the connections to the device.

Devices are normally mounted on a conducting base to which a wire connection is made. The base also acts as a heat sink which is critical for the removal of heat. The connection to the other terminal of the diode is made via a gold connection deposited onto the top surface. Gold is required because of its relative stability and high conductivity.

During manufacture there are a number of mandatory requirements for the devices to be successful - the material must be defect free and it must also have a very uniform level of doping.

The Gunn diode is not like a typical PN junction diode. Rather than having both p-type and n-type semiconductor, it only utilises n-type semiconductor where electrons are the majority carriers.

The Gunn diode operation depends upon the very thin active region for its operation, it forms an ideal low power microwave RF oscillator, although it may also be used as an RF amplifier as well.

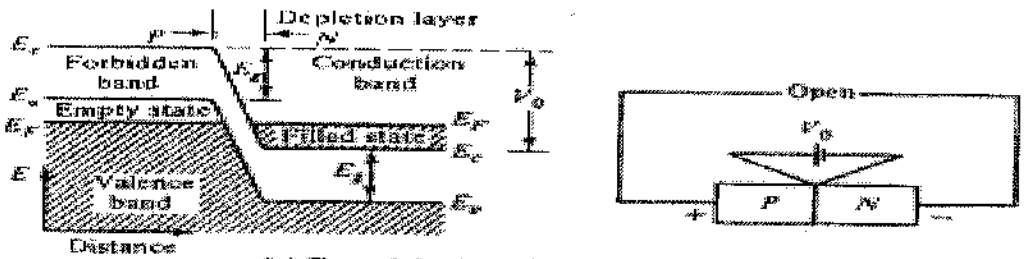
Gunn diode operation basics

The operation of the Gunn diode can be explained in basic terms. When a voltage is placed across the device, most of the voltage appears across the inner active region. As this is particularly thin this means that the voltage gradient that exists in this region is exceedingly high.

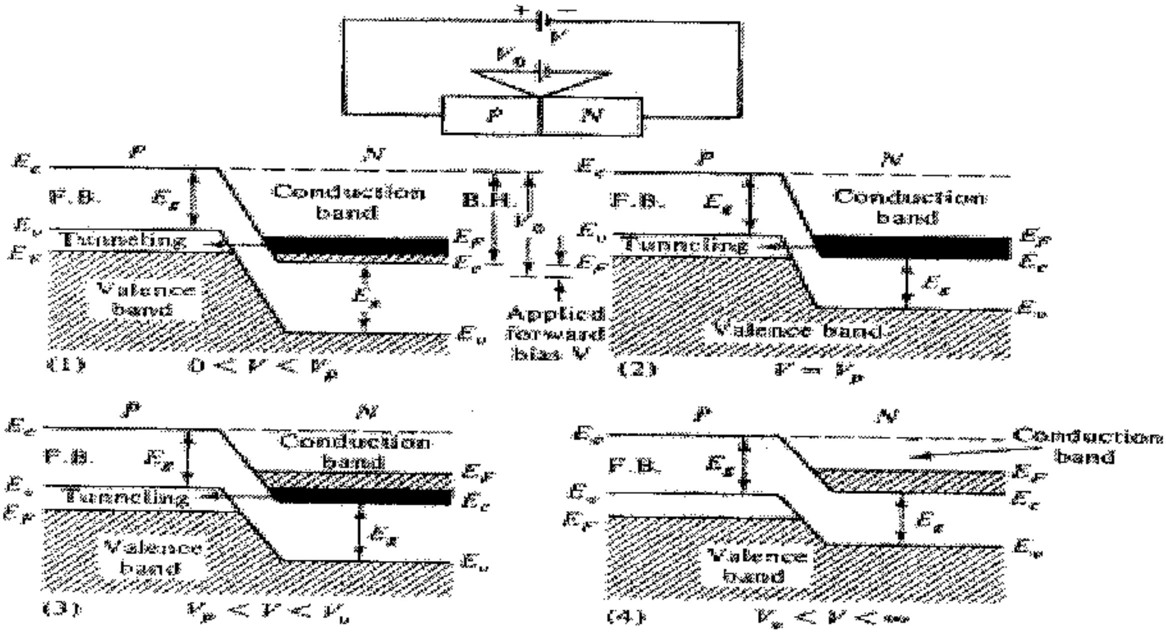
The device exhibits a negative resistance region on its V/I curve as seen below. This negative resistance area enables the Gunn diode to amplify signals. This can be used both in amplifiers and oscillators. However Gunn diode oscillators are the most commonly found.

2. **Explain the principle operation of tunnel diode with sketch the energy band diagram. (<u>4Marks</u>).**

The tunnel diode is a negative-resistance semiconductor *p-n* junction diode. The negative resistance is created by the tunnel effect of electrons in the *p-n* junction. The doping of both the *p* and *n* regions of the tunnel diode is very high-impurity concentrations of 1019 to 1020 atoms/cm3 are used-and the depletion-layer barrier at the junction is very thin, on the order of 100 Aor 10-6 cm. Classically, it is possible for those particles to pass over the barrier if and only if they have an energy equal to or greater than the height of the potential barrier. Quantum mechanically, however, if the barrier is less than 3 Athere is an appreciable probability that particles will tunnel through the potential barrier even though they do not have enough kinetic energy to pass over the same barrier. In addition to the barrier thinness, there must also be filled energy states on the side from which particles will tunnel and allowed empty states on the other side into which particles penetrate through at the same energy level. In order to understand the tunnel effects fully, let us analyze the energy-band pictures of a heavily doped *p-n* diode. the energy-band diagrams of a tunnel diode.



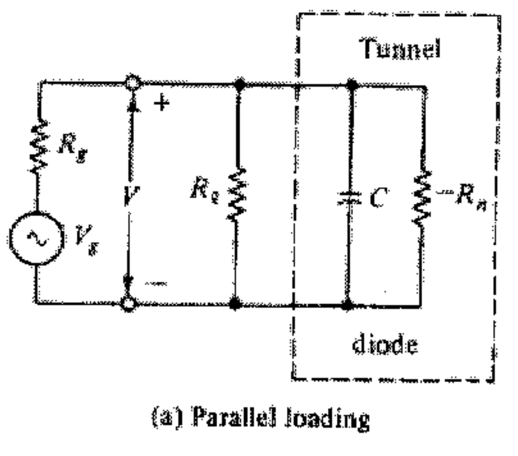
(a) Tunnel diode under zero-bias equilibrium



(b) Tunnel diode with applied forward bias

E_F is the Fermi level representing the energy state with 50% probability of being filled if no forbidden band exists
V_0 is the potential barrier of the junction
E_g is the energy required to break a covalent bond, which is 0.72 eV for germanium and 1.10 eV for silicon
E_c is the lowest energy in the conduction band
E_v is the maximum energy in the valence band
V is the applied forward bias
F.B. stands for the forbidden band
B.H. represents the barrier height

3. **Drive an expression for the power gain of the tunnel diode amplifier when connected it parallel with a resistive load? How convert it to oscillator system. (<u>4Marks</u>).**



(a) Parallel loading

Parallel loading. It can be seen from Fig. 5-3-5(a) that the output power in the load resistance is given by

$$P_{out} = \frac{V^2}{R_\ell} \tag{5-3-5}$$

One part of this output power is generated by the small input power through the tunnel diode amplifier with a gain of A, and this part can be written

$$P_{in} = \frac{V^2}{AR_\ell} \tag{5-3-6}$$

Another part of the output power is generated by the negative resistance, and it is expressed as

$$P_n = \frac{V^2}{R_n} \tag{5-3-7}$$

Therefore

$$\frac{V^2}{AR_\ell} + \frac{V^2}{R_n} = \frac{V^2}{R_\ell} \tag{5-3-8}$$

and the gain equation of a tunnel diode amplifier is given by

$$A = \frac{R_n}{R_n - R_\ell} \tag{5-3-9}$$

When the negative resistance R_n of the tunnel diode approaches the load resistance R_ℓ, the gain A approaches infinity and the system goes into oscillation.

4. **How connected tunnel diode to a microwave circulator to make a negative resistance amplifier? (3Marks).**

$$\Gamma = \frac{-R_n - R_0}{-R_n + R_0} \tag{5-3-11}$$

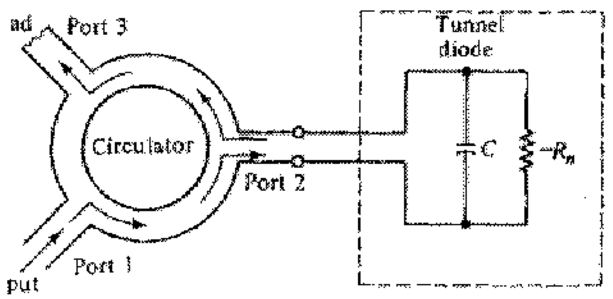


Figure 5-3-6 Tunnel diode connected to circulator.

5. **Explain the working principle of IMPATT diode comparing with PIN and shottkey diodes, and then identify the avalanche multiplication. (5Marks).**

A theoretical Read diode made of an n^+-p-i-p^+ or p^+-n-i-n^+ structure has been analyzed. Its basic physical mechanism is the interaction of the impact ionization avalanche and the transit time of charge carriers. Hence the Read-type diodes are called IMPATT diodes. These diodes exhibit a differential negative resistance by two effects:

1. The impact ionization avalanche effect, which causes the carrier current $I_0(t)$ and the ac voltage to be out of phase by 90°
2. The transit-time effect, which further delays the external current $I_e(t)$ relative to the ac voltage by 90°

Q.1 -3

Two Cavity Klystron amplifier

given $V_o = 1200V$ $F = 8GHz$
$I_o = 28\ mA$

$d = 1mm$ $L = 4\ cm$ $R_{sh} = 40K\Omega$

(a) Find The i/p M.W Voltage V_1 to generate a maximum o/p Voltage V_2.

Ans

$\because V_1 = \frac{2 V_o X}{\beta_o\ \theta_o}$?? ?? $\because X = \frac{\beta_o V_1}{2 V_o} \theta_o$

$\because$ For maximum o/p voltage V_2,
$J_1(X)$ must be maximum
$\therefore J_1(X) = 0.582$ at $X = 1.841$

$\because \beta_o = \beta_1 = \frac{\sin(\theta g/2)}{(\theta g/2)}$

$\because \theta g = \omega \tau g = \omega \frac{d}{\vartheta_o}$

$\because \vartheta_o = 0.593 * 10^6 \sqrt{V_o} = 0.593 * 10^6 * \sqrt{1200}$

$\vartheta_o = 2.1 * 10^7\ m/s$

$\therefore \theta g = 2\pi f \frac{d}{\vartheta_o} = 2\pi * 8*10^9 * \frac{1.1*10^{-3}}{2.1*10^7}$

$\therefore \theta g = 2.39$ rad [2.4 : 2.5]

$\therefore \beta_o = \beta_1 = \frac{\sin\left(\frac{2.39 * 180}{2 * \pi}\right)}{\left(\frac{2.39}{2}\right)} = 0.778$ [0.76 : 0.?]

$\theta_o = \omega T_o = \omega \frac{L}{\vartheta_o} = 2\pi * 8*10^9 * \frac{4*10^{-2}}{2.1*10^7}$

$\theta_o = 95.74$ Rad [95.74 : ?]

$$V_1 = \frac{2 V_o X}{\beta_i \theta_o} = \frac{2 * 1200 * 1.841}{0.778 * 95.74} = 59.3\ V$$

$$\therefore V_1 = 59.3\ V \qquad [57.9 : 59.3]$$

(b) Determine The Voltage gain

$$A_V = \frac{|V_2|}{|V_1|} = \frac{(\beta_o I_2) R_{sh}}{V_1} = \frac{\beta_o\, 2 I_o J_1(X)\ R_{sh}}{V_1}$$

$$= \frac{\beta_o V_1}{2 V_o}\theta_o \longrightarrow \therefore V_1 = \frac{2 V_o X}{\beta_o \theta_o}$$ بالتعويض

$$\therefore A_V = \frac{\beta_o (2 I_o J_1(X))\ R_{sh} * \beta_o \theta_o}{2 V_o X}$$

$$\therefore A_V = \frac{\beta_o^2\ I_o\ R_{sh}\, \theta_o}{V_o} * \frac{J_1(X)}{X}$$

$$A_V = \frac{(0.778)^2 (28*10^{-3}) (40*10^3) (95.74)(0.582)}{(1200)\ (1.841)}$$

$$\therefore A_V = 17.099$$

(c) Calculate The efficiency of The amplifier.

$$\eta = \frac{P_{out}}{P_{in}} = \frac{(\beta_o I_2)^2\ R_{sh}}{2\ I_o V_o} = \frac{\beta_o^2 (2 I_o J_1(X))^2 R_{sh}}{2 I_o V_o}$$

$$\eta = \frac{\beta_o^2\, 2 I_o\, J_1^2(X)\ R_{sh}}{V_o}$$

$$\eta = \frac{(0.778)^2 (2)(28*10^{-3}) (0.582)^2 (40*10^3)}{(1200)}$$

$$\therefore \eta = 38.27\ \%$$

[36.41 : 38.27]

(d) Compute the beam loading conductance & show may neglect it in calculations.

$$\because \frac{G_B}{G_o} = F[\theta_g] = \frac{1}{2}\left[\beta_o^2 - \beta_o \cos\left(\frac{\theta_g}{2}\right)\right]$$

$$\therefore G_B = \frac{G_o}{2}\left[\beta_o^2 - \beta_o \cos\left(\frac{\theta_g}{2}\right)\right]$$

$$, \because G_o = \frac{1}{R_o} = \frac{I_o}{V_o} = \frac{28*10^{-3}}{1200} = 2.3*10^{-5} \text{ mho}$$

$$\therefore G_B = \frac{2.3*10^{-5}}{2}\left[(0.778)^2 - (0.778)\cos\left(\frac{2.39*180}{2\pi}\right)\right]$$

$[2*10^{-6} : 3.73*10^{-6}]$ $\therefore G_B = 3.73*10^{-6}$ mho

$\therefore$ The beam loading resistance

$$R_B = \frac{1}{G_B} = 0.3*10^{6}\ \Omega = 0.3\ M\Omega$$

R_{sh} KΩ ≤ $R_{sh} \leq R_L$ بالمقارنة مع KΩ

في حالة التوازى المقاومة المكافئة أقل من أقل مقاومة

$\therefore$ R_B ← كأنها open circuit

⇓ can neglect it in calculation.

Q9.3

$V_o = 30\,KV$ $\quad F = 10\,GHz$ $\quad \rho_o = 10^{-7}\,C/m^3$

$I_o = 3\,A$ $\quad \beta_o = \beta_i = 1$ $\quad V_1 = 15\,V(rms)$

$R_{sh} = 1K\Omega$ i/p $\quad$ & $\quad R_{shL} = 10\,K\Omega$ o/p

(a) The plasma Frequency.

$$\omega_p = \sqrt{\frac{e\rho_o}{m\epsilon_o}} = \sqrt{\frac{e * 10^{-7}}{m\,\epsilon_o}} = 0.45 * 10^8\ rad/s$$

(b) The reduced plasma Frequency $\quad R = 0.4$

$$\omega_q = \omega_p * R = 0.4 * 0.45 * 10^8 = 0.178 * 10^8\ rad/s$$

(c) The induced Current in The o/p Cavity.

$$I_2 = \frac{1}{2}\left(\frac{I_o\,\omega}{V_o\,\omega_q}\right)\beta_o^2\,V_1$$

$$= \frac{1}{2}\left(\frac{3}{30*10^3}\right)(3529.8794) * (1)^2\,(15) = 2.647\,A$$

$$\frac{\omega}{\omega_q} = \frac{2\pi F}{\omega_q} = \frac{2\pi * 10 * 10^9}{0.178 * 10^8} = 3529.8794$$

(d) The induced Voltage in The o/p Cavity.

$$V_2 = I_2\,R_{shL} = 2.647 * 10 * 10^3 = 26.47\,KV$$

(e) The output Power delivered to The load.

$$P_{out} = |I_2|^2\,R_{shL} = (2.647)^2 * 10 * 10^3 = 70.1\ KW$$

(F) The Power gain.

$$Gain = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{|V_1|^2}\,R_{sh} = \frac{70.1 * 10^3}{(15)^2} * 10^3 = 3.1 * 10^5$$

$$Gain(dB) = 10\log_{10}(3.1 * 10^5) = 54.93\ dB$$

(g) The electronic efficiency.

$$\eta = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{V_o\,I_o} = \frac{70.1 * 10^3}{30 * 10^3 * 3} = 77.88\%$$

#17

$V_o = 30KV$ $d = 1cm$ $V_1 = 15V$ (rms)
$I_o = 3A$ $F = 8GHz$ $\beta_i = \beta_o = 1$
$\rho_o = 10^{-7}\ C/m^3$

(a) The dc electron velocity.
$$v_o = 0.593*10^6\sqrt{V_o} = 0.593*10^6\sqrt{30*10^3}$$
$$= 1.03*10^8\ m/s.$$

(b) The dc electron phase constant.
$$\beta_e = \frac{\omega}{v_o} = \frac{2\pi f}{v_o} = \frac{2\pi*8*10^9}{1.03*10^8}$$
$$= 4.89*10^2\ rad/m$$

(c) The plasma Freq.
$$\omega p = \sqrt{\frac{e\rho_o}{m\epsilon_o}} = \sqrt{\frac{e*10^{-7}}{m*\epsilon_o}} = 0.45*10^8\ rad/s$$

(d) The reduced plasma Frequency
For $R = 0.4$
$$\omega q = R\omega p = 0.4*0.45*10^8 = 0.18*10^8\ rad/s$$

(e) The reduced plasma phase constant.
$$\beta_q = \frac{\omega q}{v_o} = \frac{0.18*10^8}{1.03*10^8} = 0.173\ rad/m$$

(F) The transit time across the i/p gap.
$$\tau = \frac{d}{v_o} = \frac{10^{-2}}{1.03*10^8} = 0.097\ ns$$

(g) The modulated electron velocity leaving the i/p gap.
$$v(t_1) = v_o\left[1 + \frac{\beta_i V_1}{2V_o}\sin(\omega\tau)\right]$$
$$= 1.03*10^8\left[1 + \frac{1*15}{2*30*10^3}\sin(2\pi*8*10^9*0.097*10^{-9}*\frac{180}{\pi})\right]$$
$$v(t_1) = 1.03*10^8 + 25.26*10^3\ m/s$$

Q9.3

$V_0 = 30\,KV$ $\quad F = 10\,GHz$ $\quad \rho_0 = 10^{-7}\,C/m^3$

$I_0 = 3\,A$ $\quad \beta_0 = \beta_i = 1$ $\quad V_1 = 15\,V(rms)$

$R_{sh} = 1K\Omega$ $\quad$ & $\quad R_{shL} = 10\,K\Omega$

i/p ↲ $\quad$ o/p ↲

(a) The plasma Frequency.

$$\omega_p = \sqrt{\frac{e\rho_0}{m\epsilon_0}} = \sqrt{\frac{e * 10^{-7}}{m\,\epsilon_0}} = 0.45 * 10^8 \text{ rad/s}$$

(b) The reduced plasma Frequency $\quad R = 0.4$

$$\omega_q = \omega_p * R = 0.4 * 0.45 * 10^8 = 0.178 * 10^8 \text{ rad/s}$$

(c) The induced Current in The o/p cavity.

$$I_2 = \frac{1}{2}\left(\frac{I_0\,\omega}{V_0\,\omega_q}\right)\beta_0^2\,V_1$$

$$= \frac{1}{2}\left(\frac{3}{30*10^3}\right)(3529.8794) * (1)^2\,(15) = 2.647\,A$$

$$\frac{\omega}{\omega_q} = \frac{2\pi F}{\omega_q} = \frac{2\pi * 10 * 10^9}{0.178 * 10^8} = 3529.8794$$

(d) The induced voltage in The o/p cavity.

$$V_2 = I_2\,R_{shL} = 2.647 * 10 * 10^3 = 26.47\,KV$$

(e) The output power delivered to The load.

$$P_{out} = |I_2|^2\,R_{shL} = (2.647)^2 * 10 * 10^3 = 70.1\,KW$$

(F) The power gain.

$$\text{Gain} = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{|V_1|^2}\,R_{sh} = \frac{70.1 * 10^3}{(15)^2} * 10^3 = 3.1 * 10^5$$

$$\text{Gain (dB)} = 10\log_{10}(3.1 * 10^5) = 54.93\,dB$$

(g) The electronic efficiency.

$$\eta = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{V_0\,I_0} = \frac{70.1 * 10^3}{30 * 10^3 * 3} = 77.88\%$$

1-B } 2

$V_0 = 30KV$ $\quad d = 1cm$ $\quad V_1 = 15V$ (rms)
$I_0 = 3A$ $\quad F = 8GHz$ $\quad \beta_i = \beta_0 = 1$
$\rho_0 = 10^{-7}$ C/m³

(a) The dc electron velocity.

$$v_0 = 0.593*10^6\sqrt{V_0} = 0.593*10^6\sqrt{30*10^3}$$
$$= 1.03*10^8 \text{ m/s.}$$

(b) The dc electron phase constant.

$$\beta_e = \frac{\omega}{v_0} = \frac{2\pi f}{v_0} = \frac{2\pi*8*10^9}{1.03*10^8}$$
$$= 4.89*10^2 \text{ rad/m}$$

(c) The plasma Freq.

$$\omega p = \sqrt{\frac{e\rho_0}{m\epsilon_0}} = \sqrt{\frac{e*10^{-7}}{m*\epsilon_0}} = 0.45*10^8 \text{ rad/s}$$

(d) The reduced plasma Frequency

For $R = 0.4$

$$\omega q = R\omega p = 0.4*0.45*10^8 = 0.18*10^8 \text{ rad/s}$$

(e) The reduced plasma phase constant.

$$\beta_q = \frac{\omega q}{v_0} = \frac{0.18*10^8}{1.03*10^8} = 0.173 \text{ rad/m}$$

(F) The transit time across the i/p gap.

$$\tau = \frac{d}{v_0} = \frac{10^{-2}}{1.03*10^8} = 0.097 \text{ ns}$$

(g) The modulated electron velocity leaving The i/p gap.

$$v(t_1) = v_0\left[1 + \frac{\beta_i V_1}{2V_0}\sin(\omega\tau)\right]$$
$$= 1.03*10^8\left[1 + \frac{1*15}{2*30*10^3}\sin\left(2\pi*8*10^9*0.097*10^{-9}*\frac{180}{\pi}\right)\right]$$

$$v(t_1) = 1.03*10^8 - 25.26*10^3 \text{ m/s}$$

Q-13 - 3

Reflex Klystron $n=2$, $N=1\frac{3}{4}$

$P_{dc} = 40\ mV \longrightarrow$ i/p power

$\frac{V_1}{V_0} = 0.278$, if 20% of the power delivered by the beam is dissipated in the cavity walls.

Find the power delivered to the load.

Ans

$\because P_{dc} = I_o V_o = 40 * 10^{-3}\ W$

$\because \frac{V_1}{V_0} = \frac{2X'}{\beta_i (N 2\pi)} = 0.278$ assume $\beta_i = 1$

$\therefore X' = \frac{0.278}{2} * \frac{7}{4} * 2\pi * 1 = 1.528$

* From Figure (9-4-3) $X' J_1(X')$ versus X'.

$\therefore$ at $X' = 1.528 \longrightarrow X' J_1(X') = 0.83$

$\because P_{o/p}\big|_{ac} = \frac{2 V_o I_o X' J_1(X')}{N 2\pi} = \frac{2 * 40 * 10^{-3} * 0.83}{\frac{7}{4} * 2\pi}$

$\therefore P_{o/p} = 6.04\ mW$

$\because$ 20% power is lost in cavity walls.

$\hookrightarrow 6.04 * \frac{20}{100} = 1.21\ mW$

$\therefore$ Power delivered to the load =

$6.04 * \frac{80}{100} = 4.83\ mW$

TWT

[crossed out]

$V_o = 2KV$ $F = 8GHz$ $Z_o = 20\,\Omega$
$I_o = 4mA$ $N = 50$

* Determine:

(a) The gain parameter c.

$$C = \left(\frac{I_o Z_o}{4V_o}\right)^{\frac{1}{3}} = \left(\frac{4*10^{-3} * 20}{4 * 2*10^{3}}\right)^{\frac{1}{3}} = \boxed{21.54 * 10^{-3}}$$

(b) The power gain in decibels.

$$AP = -9.54 + 47.3\,NC$$
$$AP = -9.54 + 47.3\,(50 * 21.54 * 10^{-3}) = \boxed{41.4\,dB}$$

9-15

$I_o = 50mA$ $Z_o = 6.75\,\Omega$
$V_o = 2.5KV$ $N = 45$ $F = 8GHz$

* Determine:

(a) The gain parametere c.

$$C = \left(\frac{I_o Z_o}{4V_o}\right)^{\frac{1}{3}} = \left(\frac{50*10^{-3} * 6.75}{4 * 2.5*10^{3}}\right) = \boxed{32.32 * 10^{-}}$$

(b) The output power gain AP in decibels.

$$AP = -9.54 + 47.3\,NC$$
$$= -9.54 + 47.3\,(45 * 32.32 * 10^{-3}) = \boxed{59.25\,dB}$$

(c) All Four propagation Constants.

$$\beta_e = \frac{\omega}{v_o} = \frac{2\pi F}{0.593*10^{6}\sqrt{V_o}} = \frac{2\pi * 8*10^{9}}{0.593*10^{6} * \sqrt{2.5*10^{3}}}$$

$$\beta_e = 1.695*10^{3}\ \text{rad/m}$$

$= -\beta_e C \frac{\sqrt{3}}{2} + j\beta_e(1+\frac{C}{2})$

$= -47.45 + j1722.69$

$\gamma_2 = \beta_e C \frac{\sqrt{3}}{2} + j\beta_e(1+\frac{C}{2})$

$\gamma_2 = 47.45 + j1722.69$

$\gamma_3 = j\beta_e(1-C)$

$\gamma_3 = j1640.51$

$\gamma_4 = -j\beta_e(1-\frac{C^3}{4})$

$\gamma_4 = -j1695.28$

The wave equations for all four modes in exponential form.

① Forward wave with increasing amplitude.

$$e^{j\omega t - \gamma_1 z} = e^{j(\omega t - 1722.69z)}$$

② Forward wave with decreasing amplitude.

$$e^{j\omega t - \gamma_2 z} = e^{-47.45z} \, e^{j(\omega t - 1722.69z)}$$

③ Forward wave with const. amplitude.

$$e^{j\omega t - \gamma_3 z} = e^{j(\omega t - 1640.51z)}$$

④ Backward wave with const. amplitude.

$$e^{j\omega t + \gamma_4 z} = e^{j(\omega t + 1695.28z)}$$

Q-19 $F = 9\,GHz$ $V_o = 20\,KV$ $I_o = 3.5\,A$

$B_o = 0.3\,wb/m^2$

$Z_o = 50\,\Omega$

(a) The dc electron-beam velocity.

$$v_o = 0.593 * 10^6 \sqrt{V_o} = 0.593 * 10^6 \sqrt{20 * 10^3}$$

$$= 83.86 * 10^6 \ m/s$$

(b) The electron beam phase constant.

$$\beta_e = \frac{w}{v_o} = \frac{2\pi F}{v_o} = \frac{2\pi * 9 * 10^9}{83.86 * 10^6} = 674.2993 \ rad/m$$

(c) The cyclotron angular frequency.

$$w_c = \frac{e}{m} B_o = 1.759 * 10^{11} * 0.3 = 5.277 * 10^{10} \ rad/s$$

(d) The cyclotron phase constant.

$$\beta_m = \frac{w_c}{v_o} = \frac{5.277 * 10^{10}}{83.86 * 10^6} = 629.26 \ rad/m$$

(e) The gain parameter.

$$C = \left(\frac{I_o Z_o}{4 V_o}\right)^{1/3} = \left(\frac{3.5 * 50}{4 * 20 * 10^3}\right)^{\frac{1}{3}} \doteq 0.1298$$