
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q1A. **Attempt any THREE**:- **12M**

a) State two advantages and two applications of circular waveguide.

Ans:

Advantages: (any two) **2M**

- The circular waveguide are easier to manufacture than rectangular waveguides and are easier to join.
- The TM_{01} modes are rotationally symmetrical and hence rotation of polarization can be overcome.
- TE_{01} mode in circular for long distance waveguide transmission.

Applications: (any two) **2M**

- Rotating joints in radars to connect the horn antenna feeding a paraboloid reflector (which must rotate for tracking).
- TE_{01} mode is suitable for long distance waveguide transmission above 10GHz.
- Short and medium distance broad band communication (cold replace/share coaxial and microwave links).
- It is used where the transmission or reception is in the range of microwave frequencies.
- It is also used for handling the high power of energy.
- It is mostly used in the airborne radar.

- The circular waveguide is mostly used in the ground radar to transmit or receive the energy from antenna. Which revolves in 360 degree bearing continuously.
- The waveguide is also used in communication system.
- It can also use in the devices of navigation aids.
- The circular waveguides are also used with the cavity resonators to carry the input and output signals.

b) Draw labeled sketch of reflex Klystron. List its two application .

Ans:

Diagram: **2M**

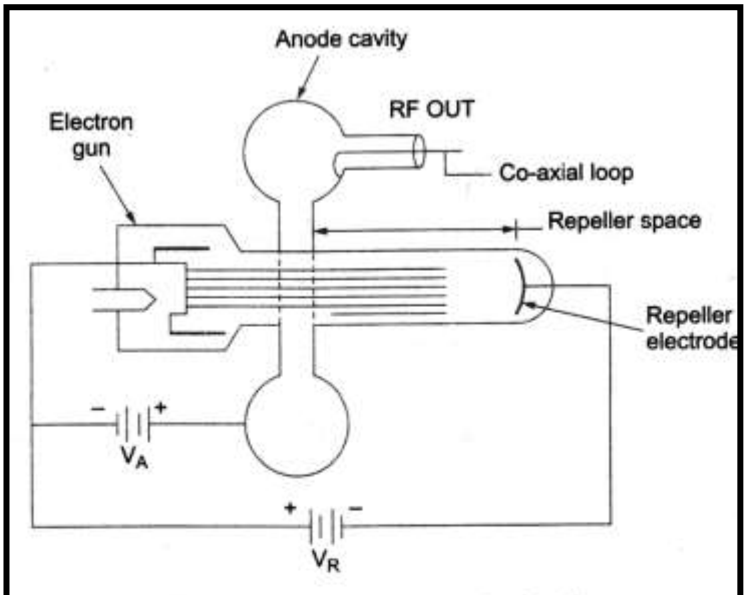


Fig. Constructional details of reflex klystron.

Applications: (any two) **2M**

This is the most widely used in applications where variable frequency is desired as

- In radar receivers.
- Local oscillator in microwave receivers.
- Signal source in microwave generator of variable frequency.
- Portable microwave links and
- Pump oscillator in parametric amplifier.

c) Define the term antenna scanning. State its types. Explain any one type of antenna scanning.

Ans:

Definition:- **1M**

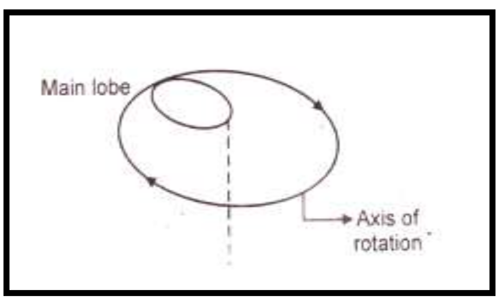
Scanning refers to way in which the antenna keeps moving in azimuth and elevation for covering an area, which has desired target. Tracking means tracking the path of target by means of radar. Antenna scans given area of surrounding space but actual scanning pattern depending on application.

Types of antenna scanning: **1M**

- Horizontal Scanning.
- Nodding Scanning.
- Helical Scanning.
- Spiral Scanning.

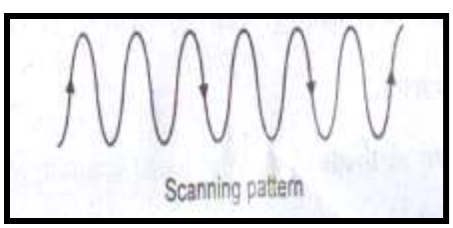
Explanation:- **2M**

1) **Horizontal Scanning**: If scanning is required in only plane it is called horizontal scanning. e.g. Ship to ship communication, navigation.



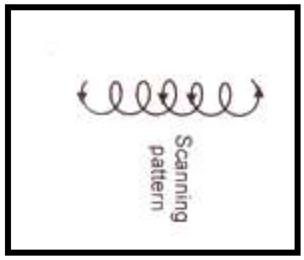
OR

2) **Nodding**: In this scanning, antenna is moved rapidly assuming in slowly in elevation. It covers limited area or complete hemisphere.



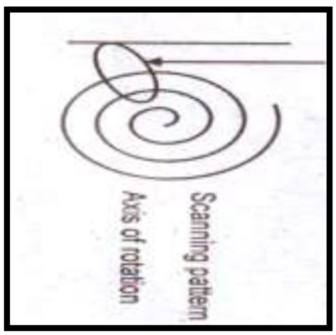
OR

3) **Helical**: Elevation is slowly raised while it rotates more rapidly in assuming. Covers complete hemisphere and it takes place in both plane. e.g. tracking of satellite.



OR

4) **Spiral**: It is required to scan limited area. When target is to be detected, scanning take place first with somewhat wide because of width. Whereas tracking is locate at exact position of target which take place with narrow phase shift beam width.



d) Define the term 'orbit' w.r.t. satellite. List different types of orbits of satellite.

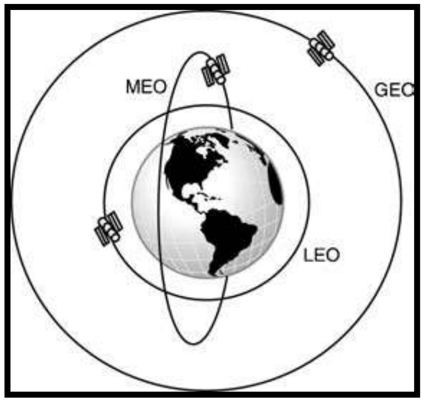
Ans:

Definition: **2M**

An orbit is a trajectory that is periodically repeated. While the path followed by the motion of an artificial satellite around Earth is an orbit

Or

Satellites travel around the earth along predetermined/predefined repetitive paths called orbits.



Types of orbit satellite: **2M**

Based on Orientation of the orbital plane –

1. Equatorial Orbit
2. Polar Orbit
3. Inclined Orbit

Based on Distance of the orbit from the Earth's surface –

1. Low Earth Orbit
2. Medium Earth Orbit
3. High Earth Orbit or GEO

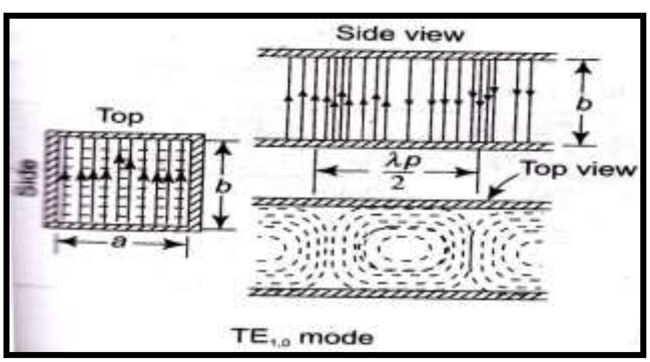
Based on eccentricity of the orbit --

1. Circular orbit
2. Elliptical orbit

B) Attempt any ONE: 6M

a) Draw field pattern of $TE_{1.0}$ mode in rectangular waveguide.

Ans: Diagram:- **6M**



OR

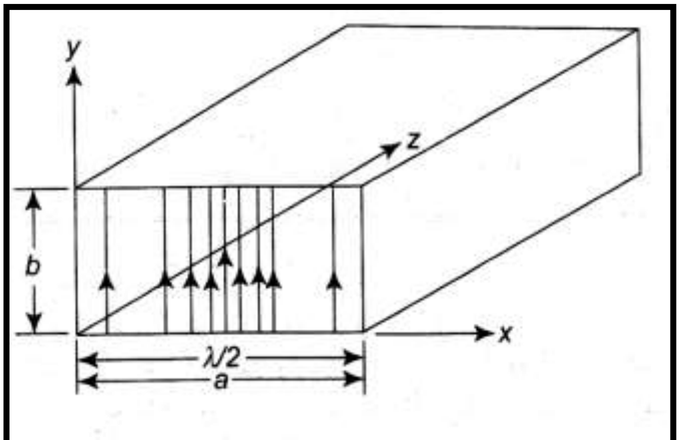


Fig. $TE_{1,0}$ mode in a rectangular waveguide.

b) Draw neat constructional diagram of IMPATT diode. Describe its working.

Ans:

Diagram:- **3M**

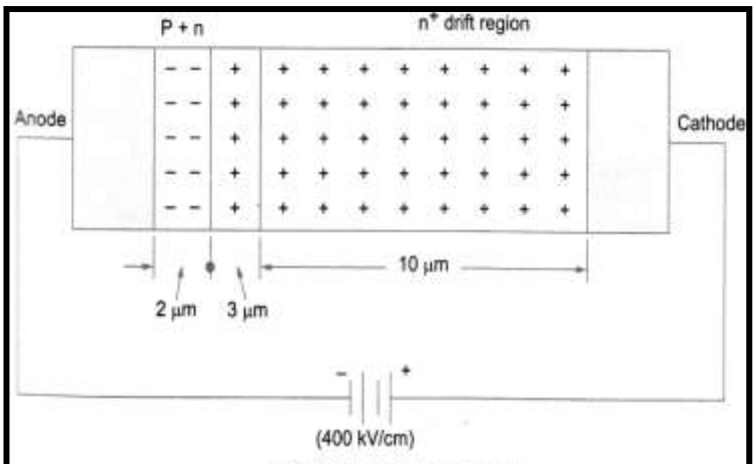


Fig. IMPATT diode schematic.

Working: **3M**

- Any device which exhibits negative resistance for dc will also exhibits it for ac i.e., If an ac voltage is applied current will rise when voltage falls at an arc rate.

- Hence negative resistance can also be defined as that property of a device which causes the current through it to be 180^0 out of phase with voltage across it.

- Thus is the kind of negative resistance exhibited by IMPATT diode i.e., If we show voltage and current have a 180^0 phase difference, then negative resistance in IMPATT diode is proved.

- A combination of delay involved in generating avalanche current multiplication together with delay due to transit time through a different space provides the necessary 180^0 phase difference between applied voltage and the resulting current in an IMPATT diode.

Q2. Attempt any FOUR. 16M

a) Compare waveguide and two wire transmission line.(Eight points).

Ans: (1/2 M each)

Comparison:

SR. NO.	WAVEGUIDES	TRANSMISSION LINES
1.	It acts as a High Pass Filter	All frequencies can pass through.
2.	It is one conductor transmission system. The whole body of the waveguide acts as ground. The wave propagates through multiple reflections from the walls of waveguide (WG).	It consists of two conductors. One or both conductors are used to carry the wave.
3.	The system of propagation in waveguide is in accordance with field theory.	The system of propagation in transmission line (TL) is in accordance with circuit theory.
4.	TE and TM modes exist in WG.	TEM mode exists in TL.
5.	Wave impedance (characteristic impedance) is a function of frequency.	Characteristic impedance in TL depends on the physical parameters of TL.
6.	The velocity of propagation of wave in WG is less than the free space velocity.	The velocity of propagation of waves is equal to free space velocity.
7.	WG handles greater power and possesses less resistance.	TL handles less power as compared to WG.
8.	Lower signal attenuation at high frequencies than TL.	Significant signal attenuation at high frequencies due to conductor and dielectric losses.

b) Write out specification of each of the followings:

i. Two cavity Klystron

ii. Magnetron

Ans:

Specification:

Two cavity Klystron: **2M**

- **Frequency**: 250 MHz to 100 GHz. (60 GHz nominal).
- **Power** : 10KW-500KW (CW) 30MW (pulsed).
- **Power gain:** 15 dB-70 dB (60dB nominal).
- **Bandwidths**: Limited (because cavity resonators are being used) 10-60 MHz- generally used in fixed frequency applications.
- **Noise figure**: 15-20dB (Sometimes greater than 25dB).
- **Theoretical efficiency**: 50% (30-40% nominal).

Magnetron: **2M**

- **Power output**: In excess of 250 kW(pulsed mode)

  10mW (UHF band)2 mW (X band)

  8 kW (at 95 GHz)
- **Frequency** : 500 MHz to 12 GHz.
- **Duty cycle** : 0.1%
- **Efficiency** : 40% to 70%

c) List different display methods used in radar. Explain any one display method.

Ans:

Types: **1M**

- A-Scope display
- B-Scope, E-Scope, & F-scope Displays
- Plan-position indicator (PPI)

Explanation: **3M**

A-scope Display :

- A beam is made to scan the CRT screen horizontally by applying a linear saw tooth voltage to the horizontal deflection plates in synchronism with the transmitted pulses.
- The demodulated echo signals from the receiver is applied to the vertical deflection plates so as to cause vertical deflections from the horizontal lines.
- In the absence of any echo signal, the display is simply a horizontal line(as in a ordinary CRO)
- As indicated in the diagram, A-scope displays range v/s amplitude of the received echo signals.
- The first 'blip' is due to the transmitted pulse, part of which is deliberately applied to the CRT for reference. In addition to this there are blips corresponding to:

i. Ground clutter i.e., echoes from various fixed objects near the transmitter and from the ground.

ii. Grass noise i.e., an almost constant amplitude and continuous receiver noise.

iii. Actual targets. These blips are usually large.

Diagram:-

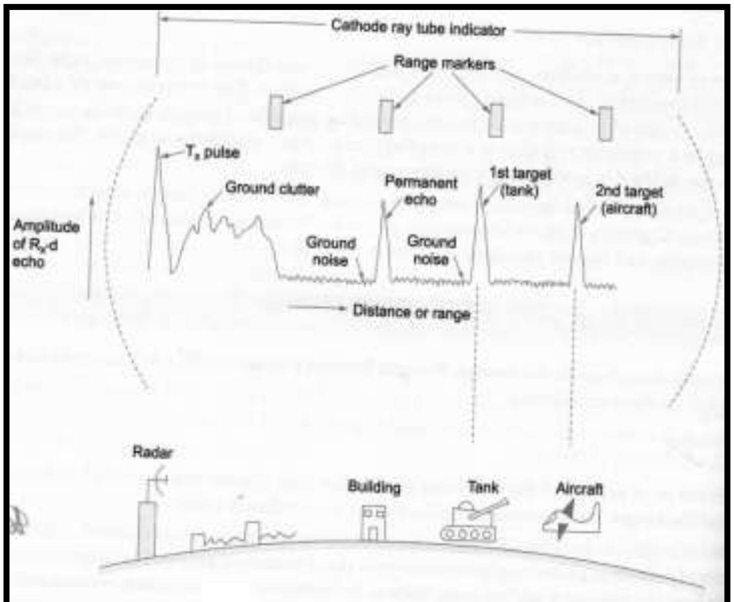


Fig. A-scope display format

OR

B-SCOPE Displays

- The B-scope displays signal amplitude as a function of azimuth. This intensity modulated display has azimuth angle along the horizontal axis and range along the vertical axis as shown in fig.
- Normally used in an airborne radar, The B-Scope display has the problem of cross range dimension getting distorted i.e., if two targets are at a constant cross range, they still appear at different separations at different ranges.

Diagram:

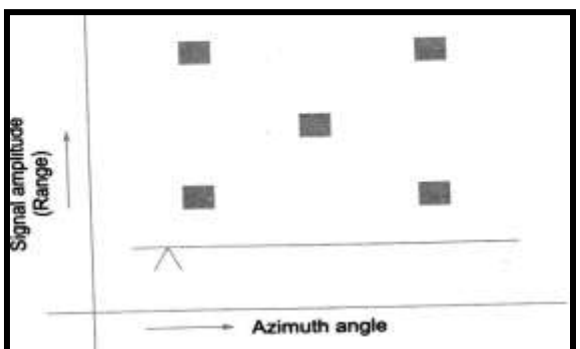


Fig. V-scope display.

E-Scope Displays

- The E-Scope display is similar to B-Scope display and displays signal amplitude as a function of range.

F-Scope Displays

- The F-Scope displays elevation track angle error (ETAE) (y-axis) as function of azimuth track angle error(ATAE) with the center of the display indicating antennas beam axis location. The displacement of the blip from the center is an indication of the position of the target wrt the antenna beam axis as shown in fig.

Diagram:

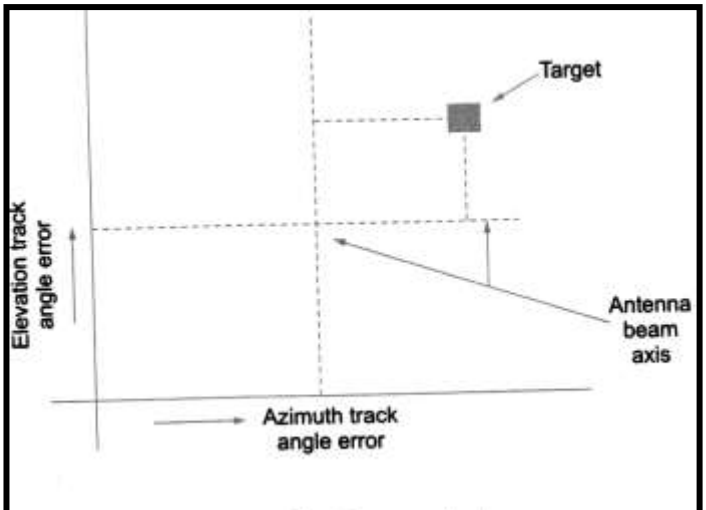


Fig. F-scope display.

Plan-Position indicator (PPI):

- This is an intensity- modulation type displays system which indicates both range and azimuth angle of the target simultaneously in polar co-ordinate as shown in figure.
- The Demodulated echo signals from the receivers is applied to the grid of the CRT which is biased slightly beyond cut-off.
- Only when Blips corresponding to the targets occur, a saw tooth current applied to a pair of coils(on opposite side of the neck of the tube) flows.
- Thus, a beam is made to deflect radially outward from the center and also continuously around the tube(mechanically) at the same angular velocity as that of the antenna.
- The brightness spot at any point on the screen indicates the presence of an objet there.
- Normally PPI screens are circular with a diameter of 30cm or 40cm. Long persistence phosphors are used to ensure that the PPI screen dose not flicker.

Diagram:-

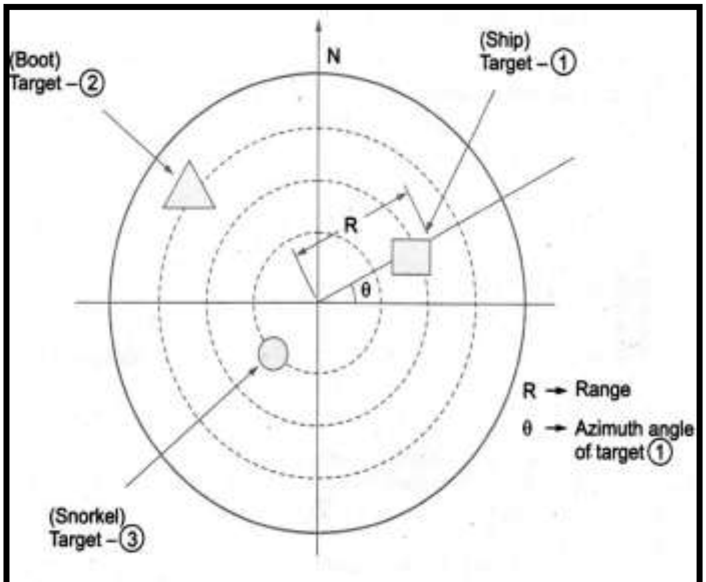


Fig. PPI display

d) State four advantages of fiber optic communications.

Ans:

Advantages: (any four) **4M**

1. **Extremely wide system bandwidth:**
Fiber systems have greater capacity due to the inherently larger BWs available with optical frequencies. Metallic cables exhibit capacitance between and inductance along their conductors. These properties cause them to act as low pass filters which limit their transmission frequencies and hence bandwidths.
2. **Immunity to electromagnetic interference:**
Fiber cables are immune to static interference caused by lightning, electric motors, fluorescent light and other external electrical noise sources. This immunity is due to the fact that optical fibers are non-conductors of electricity. Also fiber cables do not radiate RF energy and therefore cannot cause interference with other communication system.
3. **Virtual elimination of crosstalk:**
The light on one glass fiber does not interfere with light on an adjacent fiber. Fiber systems are immune to cross talk between cables caused by magnetic induction. Glass or plastic fibers are non-conductors of electricity and therefore do not have a magnetic field associated with them. In metallic cables, the primary cause of cross talk is magnetic induction between conductors located near each other.
4. **Lower signal attenuation than other propagation systems:**
Typically attenuation figure of a 1GHz BW signal for optical fibers are 0.03dB per 100 feet compared to 4dB for both coax and an X band waveguide. So, fewer repeater stations are needed as a result of glass fiber.
5. **Substantially lighter weight and smaller size:**
Fibers are smaller and much lighter in weight than their metallic counterparts. Fiber cables require less storage space and are cheaper to transport.
6. **More resistive to environmental extremes and non-corrosiveness:**

Fiber cables operate over a larger temperature variation than their metallic counterparts and fiber cable are affected less by corrosive liquids and gases. Fibers are used around volatile liquids and gases without worrying about their causing explosions.

7. **Lower cost:**
   The long term cost of fiber optics system is projected to be less than that of its metallic counterpart as the cost of copper is increasing.
8. **Conservation of the earth's resources:**
   The supply of copper and other good electrical conductors is limited whereas the principal ingredient of glass is sand and it is cheap and in unlimited supply
9. **Security:**
   Fiber cables are more secure than their metallic counterparts. It is virtually impossible to tap into a fiber cable without the user knowing about it.
10. **Safety:**
    In many wired systems, the potential hazard of short circuits requires precautionary designs. Additionally, the dielectric nature of optical fiber eliminates the spark hazard.

e) Classify fiber optic cable on the basis of

i. Modes

ii. Refractive index profile

Ans:

Classification:

Classification of fiber optic cable on the basis of modes: **2M**

- Single mode.
- Multimode.

Classification of fiber optic cable on the basis of refractive index profile: **2M**

- Step index.
- Graded index.

f) State reason for difference in uplink and downlink frequency in satellite communication.

Ans: Reasons(Any two -4 M)

- Same antenna is used for transmission & reception.
- The uplink and downlink bands are separated in frequency to prevent oscillations within the satellite amplifier while simultaneously transmission and reception.
- **Moreover low frequency band is used on the downlink to exploit the lower atmospheric losses thereby minimizing satellite power amplifier requirements.**

Q.3. Attempt any four: 16M

a) A rectangular waveguide is 5 cm by 2.5 cm. calculate the cut-off frequency of dominant mode.

Ans:-:- (Formula 1 marks, Substituting 1 marks, 2 marks answer)

The dominant mode of a rectangular waveguide is the $TE_{1,0}$ mode, with

m=1 & n=0

$$f_c = 1.5\times10^8\sqrt{\left(\frac{m}{a}\right)^2+\left(\frac{n}{b}\right)^2}$$

$$f_c = 1.5\times10^8\sqrt{\left(\frac{1}{0.050}\right)^2+\left(\frac{0}{0.025}\right)^2}$$

$$f_c = 3\ GHz$$

Or

Given : $a = 5\ cm$, $m=1$ & $n=0$

Cut off wavelength $\lambda_c = 2a$

$$\lambda_c = 2\times 5\ cm = 10\ cm = 0.01\ m$$

∴ Cut off frequency

$$f_c = \frac{c}{\lambda_c} = \frac{3\times10^8\ m/s}{10\times10^{-2}\ m} = 3\times10^9\ Hz = 3\ GHz.$$

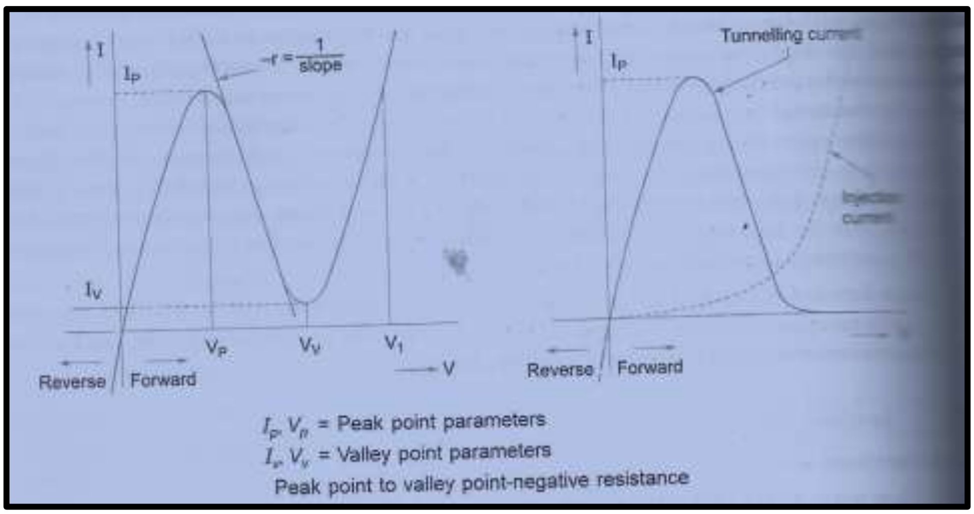
b) With neat sketch, describe operation of tunnel diode.

Ans:- (Diagram 2 marks, Description 2 marks,)

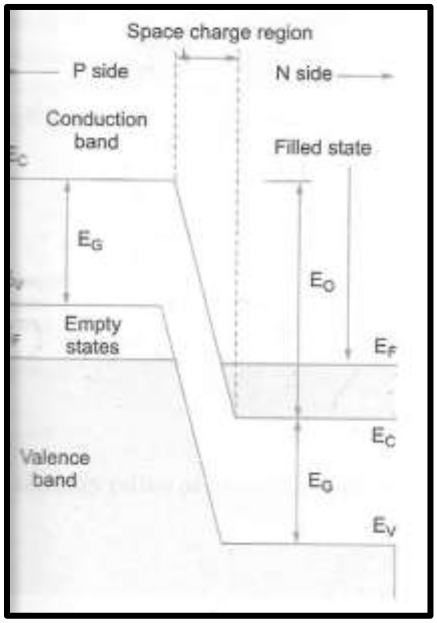
Diagram:-

1. Tunnel diode is a specially made p-n junction device which exhibits negative resistance over part of the forward bias characteristic. It has an extremely heavy doping on both sides of the junction and an abrupt transition from the p-side to the n-side. The tunneling effect is a majority carrier effect and is consequently very fast.

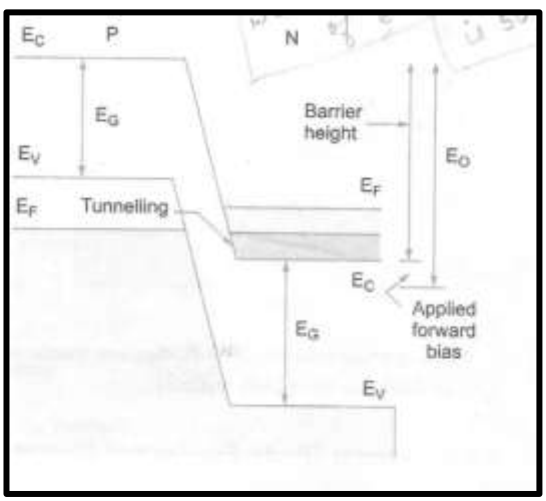
2. The tunnel effect controls the current at very low values of forward bias where the normal or the injection current is very small as shown in figure below.



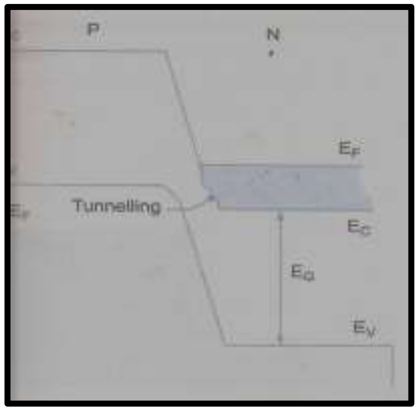
3. An electron on one side of the barrier will have a certain probability of leaking through the barrier if barrier is very thin. If both *p* and *n* type materials of a junction are heavily doped, the depletion region becomes very narrow; as narrow as the order of 100Å.
4. Another effect of heavy doping is to widen the donor level in *n* material and the acceptor level in the *p* material respectively.
5. The Fermi level also moves up into the conduction band in case of *n* material and moves down in the valence band in case of *p* type material.



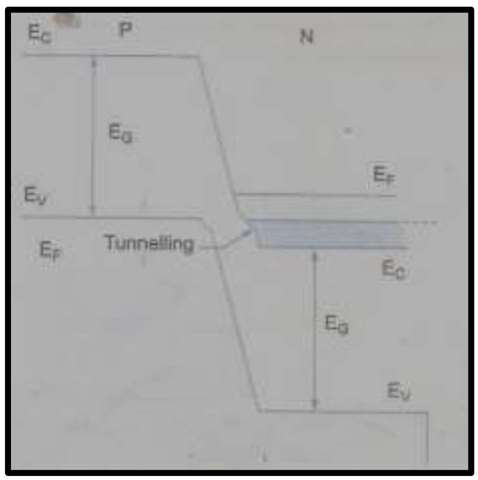
6. Under unbiased condition, there is just the same probability of electrons going from states in the conduction band on the *n* side to the states in the valence band on the *p* side, as in the opposite direction. Net tunneling on the thin barrier is then zero.
7. As forward bias is applied the energy levels on the *n* side are raised relative to those on *p* side and consequently the electrons in the conduction band on the *n* side see empty states just across the barrier and tunneling takes place.



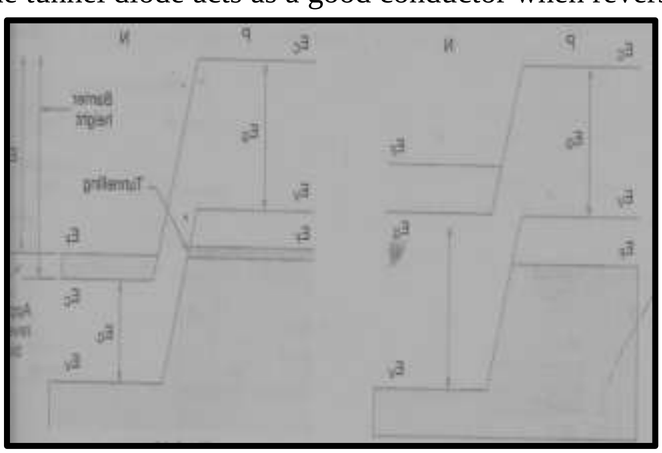
8. This tunneling current will read a maximum value I_p at a forward bias V_p of the order of 0.1V as shown in figure below.



9. As the forward bias is further increased, the energy levels on *n* side are raised so high that only part of the electrons in the conduction band sees available energy levels across the barrier as shown in figure below. Thus the tunneling current is reduced as the bias increases. This phenomenon, the suppression of tunneling, is responsible for the negative resistance part of the diode characteristic.



10. If a reverse bias voltage is applied, the height of the barrier is increased above the open circuit value E_0 as shown in fig.(f). It is observed that there are some energy states in the valence band of the *p* side which lie at the same level as allowed empty states in the conduction band of the *n* side. Hence these electrons will tunnel through from the *p* side to the *n* side, giving rise to reverse diode current. As reverse bias increases, diode current will increase. Hence the tunnel diode acts as a good conductor when reverse biased.



c) State four factors influencing maximum range of radar.

Ans:- Factors: (Each 1 marks)

1. Transmitter Power:

In case the radar range is to be doubled, we have to increase the transmitter power 16 times since Rmax α $(P_t)^{1/4}$

2. Minimum Detectable Signal:

Rmax α $(1/S_{min})^{1/4}$; thus redusing S_{min}, the receiver has to be very sensitive and gain of the R_x should be high. But R_x is more susceptible to interference as it now amplifier weak signals rather than amplifying low power received signals.

3. Frequency and Effective Area of Antenna:

Rmax α 1/√λ or Rmax α √f (∵ λ=c/f).this implies that increase in frequency increases the range. But, in a parabolic antenna, the beamwidth is given by λ/D where D is the diameter of the parabola. If λ is reduced, beamwidth becomes very narrow which reduces the tracking range of the radar. This is particularly is in case of a search radar where the sweep of the antenna that covers a portion of the sky will require a longer time. If the lobe beam width is very narrow. Thus, radar frequency cannot be increased far too much as the radar becomes ineffective although range may increase.

Also, R_{max} α √Ae. Hence, range can be increased if effective area of antenna is increased. In order to increase effective area diameter D of parabolic antenna must be increased ,which in turn reduces the beamwidth.

4.Target cross sectional area(σ):

The radar cross section of a target is the area of the target as seen by a radar. The radar cross sectional area of the target is not a controller factor.

d) State four advantages of Geostationary satellites.
Ans:- (1 marks each)
Advantages:

1. This satellite remains almost stationary in respect to a given earth station. Consequently expensive tracking equipment is not required at earth stations.
2. High altitude geosynchronous satellites can cover a much larger area of the earth than their LEO satellite counterpart.
3. There is no need to switch from one satellite to another as they orbit overhead. Consequently there are no breaks in transmission because of switching times.
4. The effects of Doppler shift are negligible.

e) Differentiate satellite communication ad fiber optic communication w.r.t. i) Frequency range ii) Electromagnetic interference iii) Application iv) Limitation

Ans:-

Comparison: (Each 1 marks)

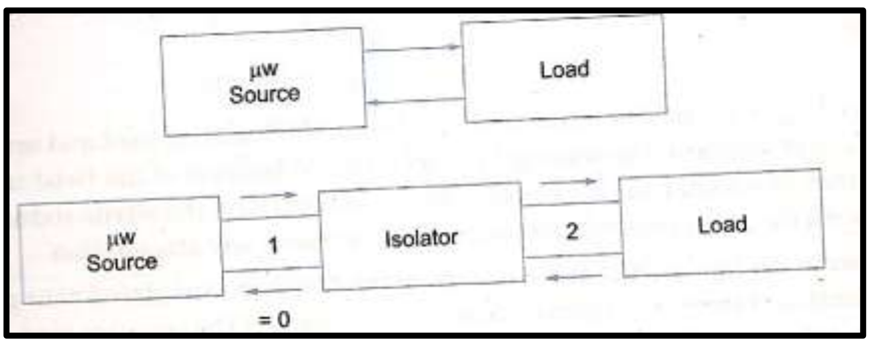
Sr. no.	**Parameter**	**Satellite communication**	**Optical fiber communication**
1	**Frequency range**	1GHz to 100GHz	10^{14}Hz to 10^{15}Hz
2	**Electromagnetic interference**	Not Immune to EM interference	Immune to EM interference
3	**Application**	i) It provide information regarding weather, make forecast about rains and cyclones. ii) It provides communication, remote sensing etc. iii) Used in mobile communication.	i) TV studio to transmitter interconnection illuminating microwave radio link ii) Secure communication system at military basis. iii)Data acquisition of control signal communication in industrial presses control system
4	**Limitation**	i) Launching and positioning of satellite is costlier, elaborated and need high technology. ii) Repel is nearly impossible after launching the satellite.	i) Difficulty in termination of fiber optics cable. ii) Fragility

Q.4. A) Attempt any three: 12

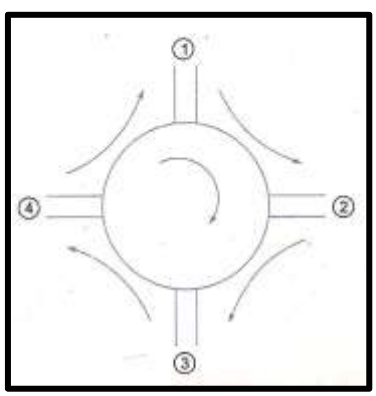
a) State function of following waveguide components:
i) Isolator ii) Circulator
Ans:- (Diagram 2 marks, function 2 marks)
Function:

i. **Isolator**: An isolator is a 2 port device which provides very small amount of attenuation for transmission from port 1 to port 2 but provides maximum attenuation for transmission from port 2 to port 1. This is very desirable when we want to match a source with a variable load.

When an isolator is inserted between the microwave generator and the load, generator is coupled to the load with zero attenuation and reflections if any from the load side are completely absorbed by the isolator without affecting generator output.

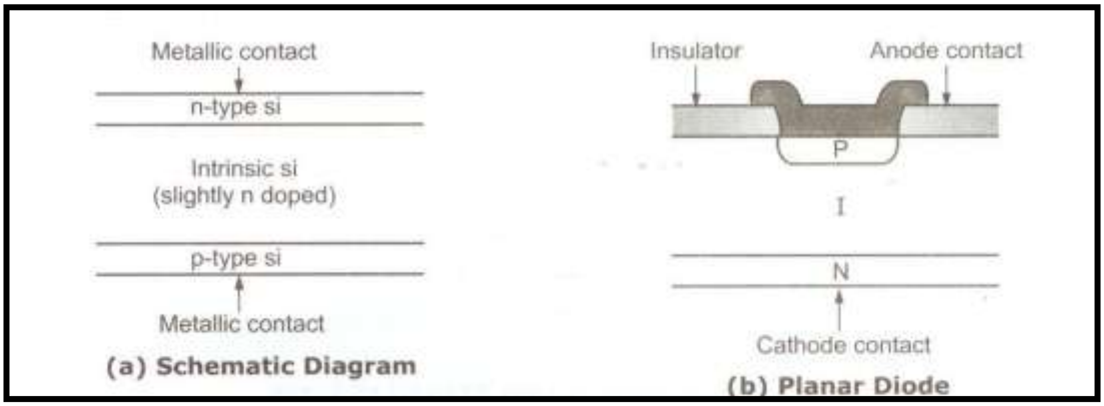


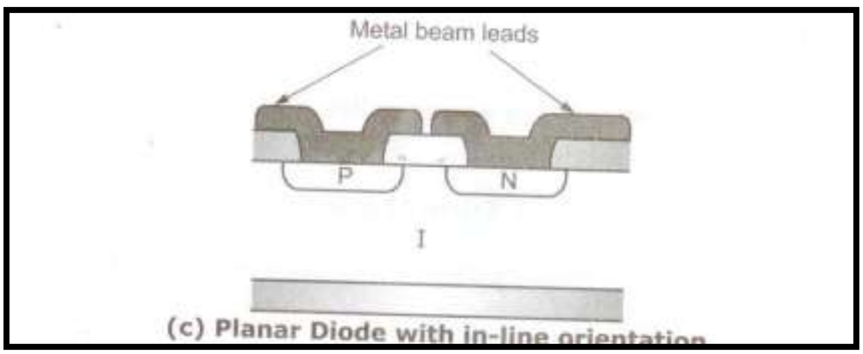
ii. **Circulator**: A circulator is a 4 port microwave device which has a property that each terminal is connected only to the next clockwise terminal. They are useful in parametric amplifiers, tunnel diode, amplifiers and duplexers in radars.



b) Draw construction diagram of PIN diode and describe its working.

Ans:- (Any one constructional diagram 2 marks, Description 2 marks)



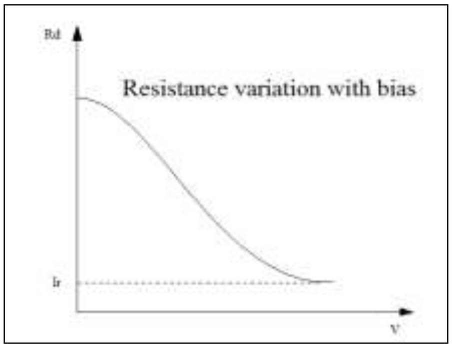


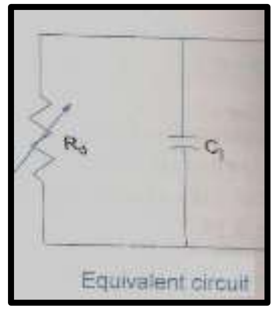
Working:

The PIN diode has following modes of operation:

1. Forward biased:

1. When the diode is forward biased, it behaves as if it possesses a variable resistance controlled by the applied current.
2. When a PIN diode is forward biased, holes and electrons are injected from the P and N regions into the I-region.
3. This results in the carrier concentration in the I layer becoming raised above equilibrium levels and the resistivity drops as forward bias is increased. Thu low resistance is offered in the forward direction.





4. The high-frequency resistance is inversely proportional to the DC bias voltage applied to the diode. A PIN diode, suitably biased, therefore acts as a variable resistor. This high-frequency resistance may vary over a wide range from 0.1Ω to 10 kΩ.

2. Reverse biased:

When the diode is reversed biased the space charge regions in the p and n layers will become thicker. The reverse resistance will be very high and almost constant.

3. Zero Bias:

At zero bias, the diffusion of the holes and electrons across the junction causes space charge region of thickness inversely proportional to the impurity concentration. The diode has high impedance.

c) Explain Radar Beacon. State its two applications.
Ans:- (Explanation 2 marks, Application 2 marks)

Explanation:-

- A Radar beacon is a small radar set consisting of a receiver, a separate transmitter and an antenna which is often omnidirectional.
- When another radar transmits a coded set of pulses at the beacon i.e it interrogates it, the beacon responds by sending back its specific pulse code.
- The pulse from the beacon or transponder may be at the same frequency as those from the interrogating radar, in which case they are received by the main station together with its echo pulses.
- They may alternatively be at a special beacon frequency, where a separate receiver is required by the interrogating radar.
- The beacons does not transmit pulses continuously in the same way as a search or tracking radar but only to the correct interrogation.

Applications ;-(any 2 points)

Radar beacons are used as:

i) One of the application of a beacon may be to identify itself. The beacon may be installed on a target (aircraft) and will transmit a specific pulse code when interrogated these pulses then appear on the PPI of the interrogating radar and inform it of the identity of the target. The system is used in airport traffic control and also for military purpose, where it is called identification, friend or foe (IFF).

ii) Another use is similar to that of lighthouses, except that radar beacons can operate over much larger distances.

d) Define following terms w.r.t. satellite.
i) look angle, ii) foot print, iii) station keeping, iv) Elevation angle.
Ans:- (Each 1 marks)
Definition:

i**) Look angle**: To orient an earth station antenna towards a satellite so that transmission and reception can be maximized, it is necessary to know the elevation and azimuth angle. These are called as look angles.

Azimith angle and elevation angle are jointly referred to as the antenna look angle.

ii) **Foot print**: The geographical representation of a satellite antenna radiation pattern is called foot print. The foot print of a satellite is the earth area that the satellite can receive from and transmitted to.

iii) **Station keeping**: The process of the firing the rocket underground control to maintain or adjust the orbit is referred to as station keeping. Once the satellite is in the orbit, the forces acting on it tends to keep it in place. If the satellite speed and height, during launch are accurately controlled, the satellite will entered in the proper orbit and remains there.

iv) **Elevation angle**: Elevation angle is the vertical angle formed between the direction of travel of an electromagnetic wave radiated from an earth station antenna pointing directly towered a satellite and the horizontal plane.

Or

It is the angle subtended between the line of sight joining the earth station antenna and the satellite and the horizontal plane

4. B) Attempt any one : **06**

a. A silica optical fibre with core diameter large enough to be considered by ray theory analysis has core refractive index of 1.50 and cladding refractive index of 1.47 calculate i)critical angle ii)NA of fibre iii) Acceptance angle in air for fibre.

Ans:- (Formula for each 1 marks, each answer 1 marks)

Given:

$n_1 = 1.50$
$n_2 = 1.47$

To find:

$\theta_c = ?$
$NA = ?$
$\theta_A = ?$

) Critical angle:

$$\theta_c = \sin^{-1}\frac{n_2}{n_1} = \sin^{-1}\frac{1.47}{1.50} = 78.52°$$

$\therefore$ $\boxed{\theta_c = 78.52°}$

i) Numerical aperature:

$$NA = \sqrt{n_1^2 - n_2^2} = \sqrt{(1.50)^2 - (1.47)^2} = \sqrt{2.25 - 2.16} = 0.30$$

$\therefore$ $\boxed{NA = 0.30}$

iii) Acceptance angle:

$$\theta_A = \sin^{-1} NA = \sin^{-1}(0.30) = 17.45°$$

$\boxed{\theta_A = 17.45°}$

b. Derive Radar range equation for noise free atmosphere.

Ans:- (Equation 1,2,3,5,6,7 –one marks each)

Note: Explanation is optional

Equations:

Let transmitted pulsed power is P_t (Peak value) and the antenna is isotropic, then the power density at a distance r from the antenna will be as given by

$$P = \frac{P_t}{4\pi r^2} \qquad \text{--------1}$$

However, antenna used in radar are directional. If A_p is the maximum power gain of the antenna used for transmission, so the power density at the target will be.

$$P = \frac{A_p P_1}{4\pi r^2} \qquad \text{--------2}$$

The Power intercepted by the target depends on its radar cross-section, or effective area. If this area is S, the power impinging on the target will be

$$P = PS = \frac{A_p P_t S}{4\pi r^2} \qquad \text{---------3}$$

The power density of its radiation at the receiving antenna will be

$$\boldsymbol{P}' = \frac{P}{4\pi r^2} = \frac{A_p P_t S}{(4\pi r^2)^2} \qquad \text{---------4}$$

The receiving antenna intercepts a portion of the reradiated power, which is proportional to the cross sectional area of the receiving antenna. However, it is the capture area of the receiving antenna that is used here. The received power is.

$$\mathbf{P}' = P' A_0 = \frac{A_p P_t S A_0}{(4\pi r^2)^2} \qquad \text{---------5}$$

Where A_0 = Capture area of the receiving antenna.

If the same antenna is used for both reception and transmission, that the maximum power gain is given by

$A_p = \frac{4\pi A_0}{\lambda^2}$ ---------6

Substituting equation 6 into 5 gives

$\mathbf{P'} = \frac{4\pi A_0}{\lambda^2} \frac{P_t SA_0}{16\pi^4 r^2} = \frac{P_t A^2{}_0 S}{4\pi r^4 \lambda^2}$

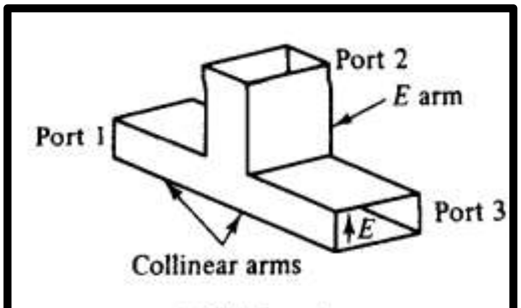
The maximum range r_{max} will be obtained when the received power is equal to the maximum receivable power of the receiver ,P_{min}

$R_{max} = \left(\frac{P_t A^2{}_0 S}{4\pi r^4 \lambda^2}\right)^{1/4}$

Q.5 Attempt any FOUR: 16M

a) Draw and describe the working of E- plane tee.

Ans: (Diagram -2M, Explanation-2M)



(a) E-plane tee

Explanation:

The E-plane tee is a voltage or series junction. Each junction is symmetrical about the central arm, so that the signal to be split up is fed into it or signals to be combined are taken from it. Some form of impedance matching is required to prevent unwanted reflections. (When $\boldsymbol{TE_{1,0}}$mode is made to propagate into port 3, the two outputs at port 1 and port 2 will have a phase shift of 180° as shown in figure (a.)). Also, when powers entering port 1 and 3 are in phase opposition, maximum energy comes out of port 2.

An input at port 2 equally divides between ports 1 and 3 but introduces a phase shift of 180° between the outputs. Hence E-plane Tee also acts as a 3dB splitter.

b) Draw constructional diagram of two cavity Klystron. List its two applications.

Ans: (Diagram 2M, Applications 2M)

Diagram:

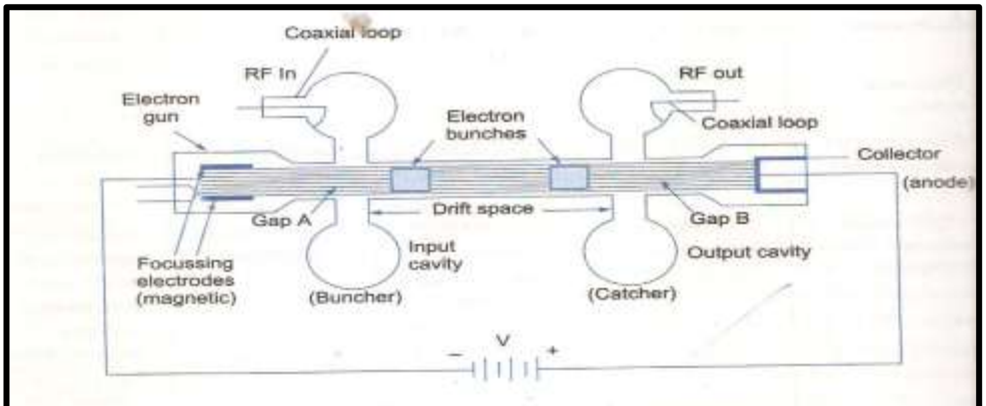


Fig. 8.9 Two cavity klystron amplifier.

Applications: (Any two)

- Used in satellite earth station transmitter as power amplifier.
- Used in UHF TV amplifier.
- It is used as a medium, high and very high power amplifier in the UHF and microwave ranges.
- Used as radar transmitter.

c) Draw and explain the block diagram of OTDR.

Ans: (2M-diagram 2M explanation)

Diagram:

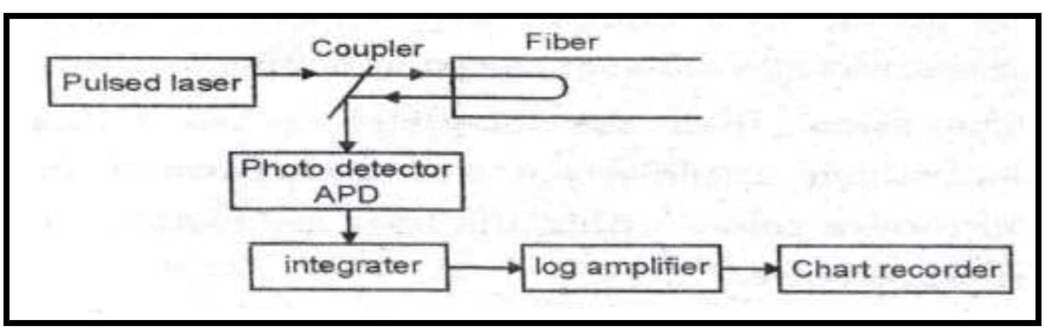


Fig. Block diagram of OTDR

Explanation:-

- A light pulse is launched into the fiber in the forward direction from an injection laser using either a directional coupler or a beam splitter.
- Beam splitter or coupler makes possible to couple the optical power impulse into the tested fiber and simultaneously to deviate the backscattered power to the optical receiver.
- The backscattered light is detected using avalanche photodiode receiver. Output of photodiode receiver drivers an integrator.

d) Draw block diagram of satellite subsystem.

Ans: (Diagram-4M)

Diagram:

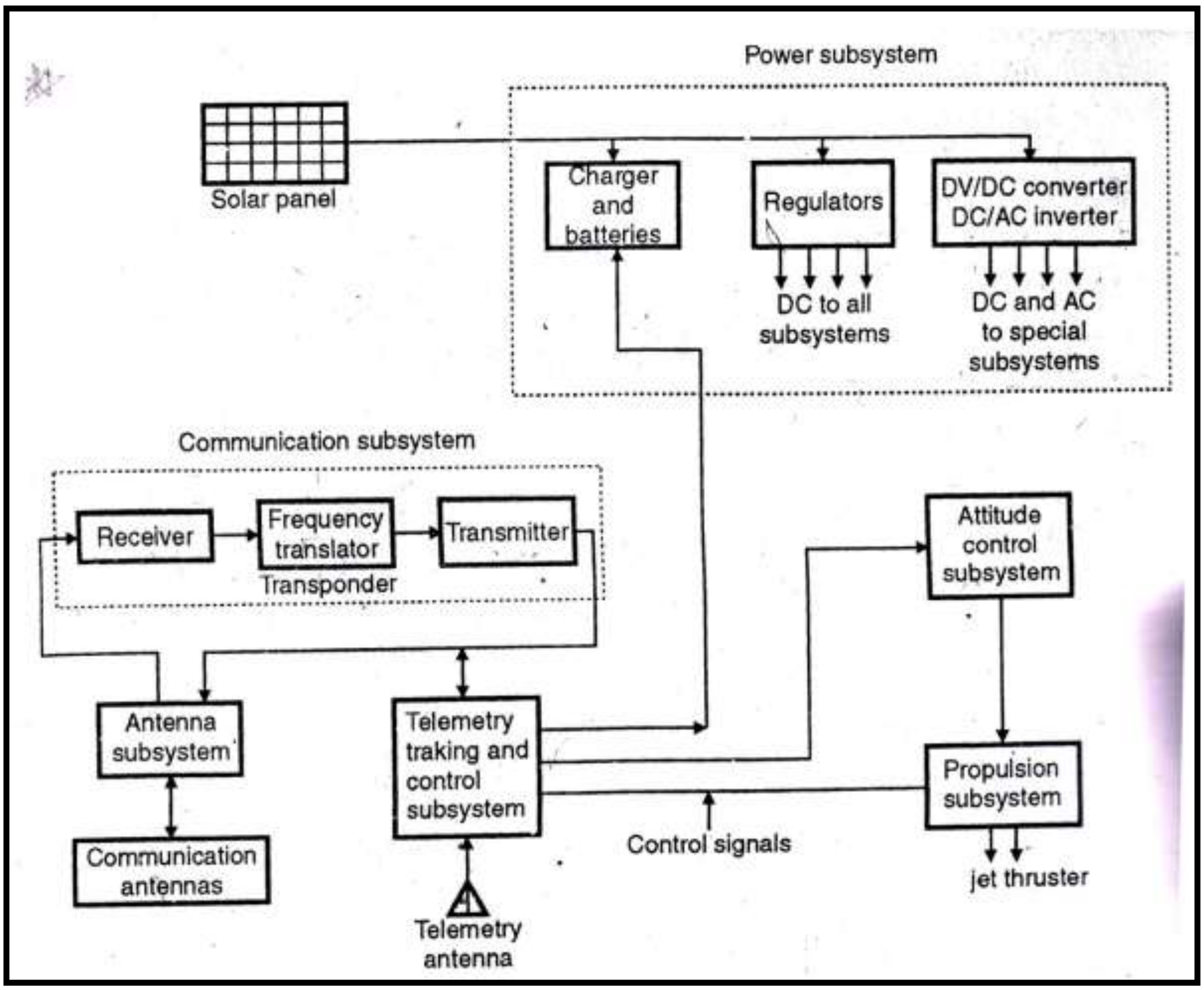


Fig. Block diagram of satellite subsystem

e) Calculate critical angle of incidence between two substances with different refractive indices n_1 =1.4 and n_2 = 1.36.

Ans: (formula 2M and answer 2M)

Given data: - $n_1 = 1.4$

$n_2 = 1.36$

n_1 = core Refractive index,

n_2 = Cladding Refractive index

Critical angle θc:-

$$\theta c = \text{Sin}^{-1}\left(\frac{n2}{n1}\right)$$

$$\theta c = \text{Sin}^{-1}\left(\frac{1.36}{1.4}\right)$$

$$\theta c = 76.27^{\circ}$$

f) State splicing techniques used for optical fiber. Explain any one in detail.

Ans: (State-1M, Diagram-2M, explanation-1M)

Different types of splicing are:

1. Fusion splicing or welding
2. Mechanical splicing
3. Elastic tube splicing

FUSION splicing:-

It is accomplished by applying localized heating i.e by a flame or an electrical arc at an interference between two butted, pre aligned fiber ends.

The figure shown below:

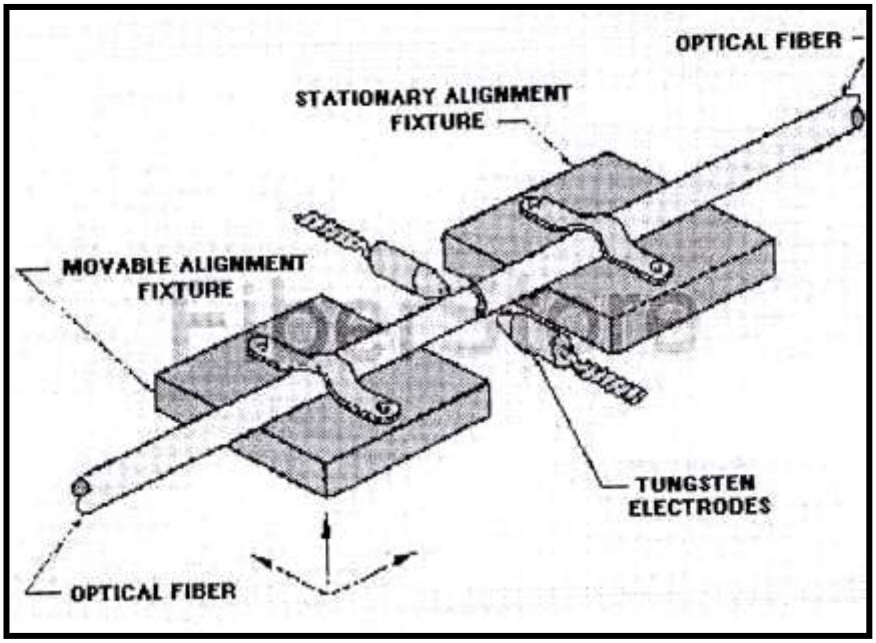


Fig. FUSION splicing

- This technique involves heating of two prepared fiber ends to their fusing point by applying sufficient axial pressure between the two optical fibers.
- For heating most widely source is electric arc.
- Following are steps for fusion process
- PREFUSION: It is a technique, which involves the rounding of the fiber ends with a low energy discharge before pressing the fibers together.
- By moving movable block, with proper pressure two fibers are pressed together
- Then there will be accomplishment of splice.

(OR)

MECHANICAL splicing:

- Using rigid alignment tube.
- In this method accurately produced rigid alignment tube is used to bond the prepared fiber ends permanently
- Figure shows the snug tube splicing.

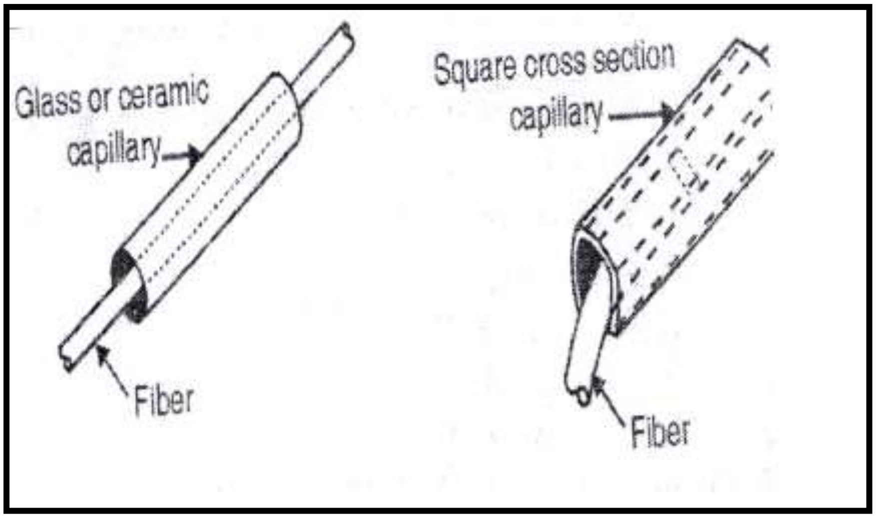


Fig. MECHANICAL splicing

- In snug tune splicing technique uses a glass or ceramic capillary tube with an inner diameter just large enough to accept the optical fibers.
- Transparent adhesive is injected through a transverse bore in capillary to give mechanical sealing and index matching of the splice.
- Average insertion losses as low as 0.1dB have been obtained
- . Figure shows the loose tube splice.
- In this splice an oversized square section metal is used to accept the prepared fiber ends.
- Transparent adhesives are first inserted into the tube followed by the fibers.
- The splice is self-aligned, when fibers are curved in a same plane.
- Mean splice insertion losses of 0.73dB have been achieved.

OR

Using V-grooves:

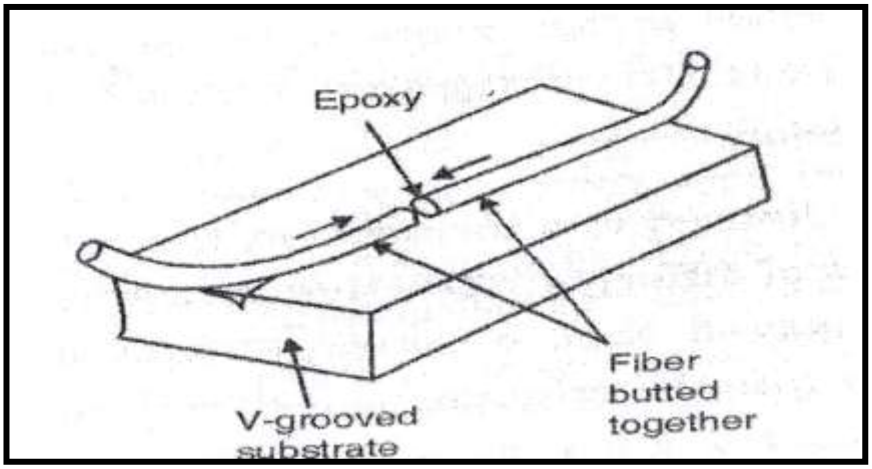


Fig. V-grooves

• In this technique V-grooves are used to secure the fibers to be joined

.• This method utilizes a V-groove into which the two prepared fiber ends are pressed.

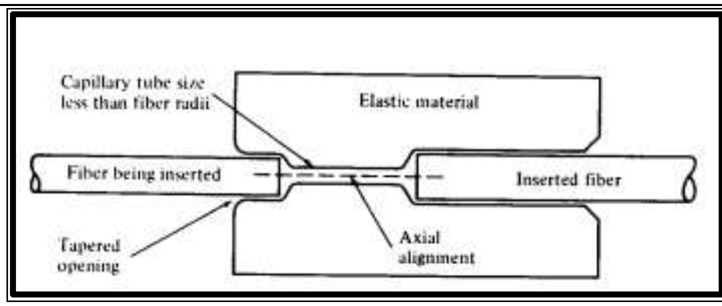
• The V-groove splice ends through insertion in the groove.

• The splice is made permanent by securing the fibers in the V-grooves with epoxy resin. • For single mode fiber splice insertion losses of less than 0.01 Db.

OR

ELASTIC TUBE SPLICE:

1. The elastic tube splice shown cross sectionally in the figure below is a unique device that automatically performs lateral, longitudinal and angular alignment.
2. It splices multimode fibers with losses in the same range as commercial fusion splices, but much less equipment and skill are needed.
3. The splice mechanism is basically a tube made of elastic material. The central hole diameter is slightly smaller than that of the fiber to be spliced and is tapered on each end for easy fiber insertion.
4. When the fiber is inserted, it expands the hole diameter so that the elastic material exerts a symmetrical force on the fiber.
5. This symmetry feature allows an accurate and automatic alignment of the axes of the two joined fibers.
6. A wide range of diameters can be inserted into the elastic tube. Thus the fibers to be spliced do not have to be equal in diameter, since each fiber moves into position independently relative to the tube axis.



Schematic of an Elastic Tube Splice.

Q.6 Attempt any FOUR: 16M

a) Explain the concept of dominant mode in waveguide.

Ans: (Explanation-4M)

Explanation:-

- The walls of the waveguides can be considered as nearly perfect conductors.
- Therefore, the boundary conditions require that electric field be normal i.e., perpendicular, to the waveguide walls.
- The magnetic fields must be tangential i.e., parallel to the waveguide walls. Because of these boundary conditions a zero subscript can exist in the TE mode but not in the TM mode. For e.g., TE_{10}, TE_{01}, TE_{20}, etc. modes can exist in a rectangular waveguide but only the TM_{11}, $TM_{12,}$ TM_{21} etc. modes can exist.
- Also the cut-off frequency relationship shows that the physical size of the waveguide determines the propagation of modes depending on the values of m and n.
- The minimum cut-off frequency for a rectangular waveguide is obtained for a dimension a>b for m= 1 and n= 0, i.e., TE_{10} mode is the dominant mode for a rectangular waveguide.(Since for TM_{mn} modes m# 0or n# 0, the lowest order mode TE_{10} is the dominant mode for a> b.)

b) Compare LED and LASER. (8 points)

Ans: (each point ½ marks)

Comparison:-

Sr No.	LED	LASER
1	Low efficiency	High efficiency
2	Response time is slow	Response time is fast.
3	Lower data transmission rate.	Higher data transmission rate.
4	Used for lower transmission distances.	Used for greater transmission distances.
5	Dispersion is less.	Dispersion is more.
6	Less temperature sensitive.	More temperature sensitive.
7	Lower bit rate.	Higher bit rate.
8	Life time is more.	Life time is less.
9	Broad output spectrum.	Narrow output spectrum.
10	Provide more distortion at output.	Provide less distortion at output.

c) What is intermodal and intramodal dispersion?

Ans: (intermodal dispersion-2M , intramodal dispersion-2M)

Dispersion is related to the difference between the transit time of signal arriving at the output.

1. Intermodal dispersion:

i. This is called as multimode dispersion.

ii. If the two light rays having same frequency follows different path while travelling through fiber optic cable. Then these rays appear at different time period at the output. Called as intermodal dispersion or pulse dispersion.

2. Intramodal dispersion:

Intramodal dispersion depends upon the material dispersion, waveguide dispersion and cross product dispersion.

i. **Material dispersion**: It depends on material used to manufacture the fibre optic cable. This wavelength.

ii. **Waveguide dispersion**:

- This is related to the bandwidth and waveguide configuration.
- Optical frequency of the signal changes the group velocity also get changed.

d) Compare step index and graded index fiber. (Any four points)

Ans: Comparison :- (each point 1M)

Sr No.	**Step index fiber**	**Graded index fiber**
1.	Step index fiber exhibit for intermodal dispersion.	Graded index fiber exhibit for less intermodal dispersion than multimode step index fiber due to refractive index profile.
2.	Multimode step index fibers have small transmission bandwidth.	Graded index fibers have larger transmission bandwidth than step index fiber.
3.	Sudden change in refractive index from core to cladding.	Gradual variation in refractive index while passing from center of the core to cladding layer.
4.	Step index fiber accepts light than graded index fiber.	Graded index fiber accepts less light than step index fiber.

e) Write uplink and downlink frequencies for C-band, X-band, Ku band and Ka band.

Ans: (each band of frequency 1M-uplink & downlink)

Band Name	**Uplink frequency**	**Downlink frequency**
C	5.9 to 6.4	3.7 to 4.2
X	7.9 to 8.4	7.25 to 7.75
Ku	14 to 14.5	11.7 to 12.2
Ka	27.5 to 30	17 to 20