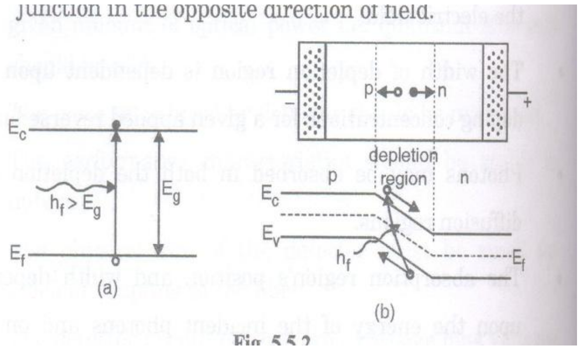
MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC – 27001 – 2005 Certified)

WINTER – 12 EXAMINATION
Model Answer

Q1. A	**Attempt any three**	**Marks 12**
Ans : a	Define following terms : i) Phase velocity ii) Group velocity Sol :i) Phase velocity :It is defined as the rate at which the wave changes its phase in terms of guide wavelength. The Phase velocity of mode is given by $V = \frac{\omega}{\beta}$.It is a function of frequency. At the cutoff of a mode , phase velocity is infinite. ii) Group velocity :It is defined as the rate at which the wave propagates through the wave guide and is given by vg = $\frac{d\omega}{d\beta}$.Group velocity is always less than speed of light .Group velocity in waveguide is the speed at which electromagnetic wave travels in a waveguide. Product of group velocity and phase velocity is square of light speed.	2+2
Ans : b	State working principle of PIN diode and state its four applications P-i-n photo diode In order to allow operation at longer wavelength where the light penetrates more deeply in to the semiconductor material a wider depletion region is necessary. To achieve this the n-type material is doped so that it can be considered as intrinsic and to make a low resistant contact a highly doped n-type (n^+)layer is added. In fig. device structure consist of p and n regions separated by very lightly doped intrinsic (i) region.  Normally sufficient large reverse bias voltage is applied across the device so that the intrinsic regions is fully depleted of carriers When an incident photon has energy greater than or equal to the band gap energy of semiconductor material, the photon can give up its energy and	2+2

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excite an electron from valence band to conduction band.
This process generates free electrons and hole pairs which are called as photo carriers.
In photo detector photo carriers are generated in the depletion region where most of incident light is absorbed.
The high electric field present in depletion region causes the carrier to separate and be collected across the reverse bias junctions.
This gives rise to current flow in external circuit.

Applications of PIN Diode : (Any four)

1)RF Switches
2)Attenuators
3)Photo detectors
4)Phase Shifters
5)Limiters

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<td>Ans : c</td>
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State RADAR Range equation and state significance of each term.

$$S_{min} = \frac{P_t\, G\, A\, A_R}{8\pi^2 \left(R^2_{max} \right)^2}$$

$$S_{min} = \frac{P_t\, G\, A\, A_R}{8\pi^2 R^4_{max}}$$

$$R_{max} = \left(\frac{P_t\, G\, A\, A_R}{8\pi^2 S_{min}} \right)^{1/4} = \left(\frac{P_t\, G}{(4\pi)^2} \right.$$

But transmitter gain = $G = \frac{4\pi A_R}{\lambda^2}$

(∵ from antenn

when λ = wavelength of radiated energy

G = transmitter gain

A_R = capture area of receiving antenn

Since radar uses the same antenna f transmitter and receiver.

$$\therefore\ R_{max} = \left(\frac{P_t \frac{4\pi A_R}{\lambda^2} A\, A_R}{(4\pi)^2 S_{min}} \right)^{1/4}$$

$$R_{max} = \left(\frac{P_t\, A\, A_R^2}{4\pi\, \lambda^2\, S_{min}} \right)^{1/4}$$

and $$A_R = \frac{G\lambda^2}{4\pi}$$

$$\therefore\ R_{max} = \left(\frac{P_t \left(\frac{G\lambda^2}{4\pi} \right)^2 A}{4\pi\lambda^2\, S_{min}} \right)^{1/4}$$

$$\boxed{R_{max} = \left(\frac{P_t\, G^2\, \lambda^2\, A}{(4\pi)^3\, S_{min}} \right)^{1/4}}$$
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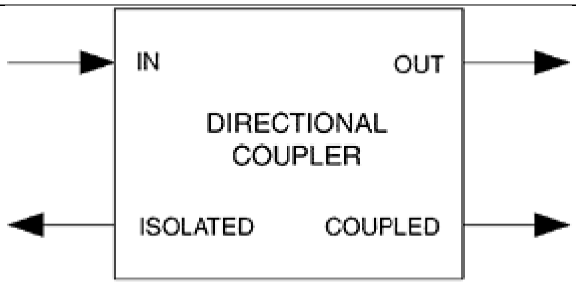
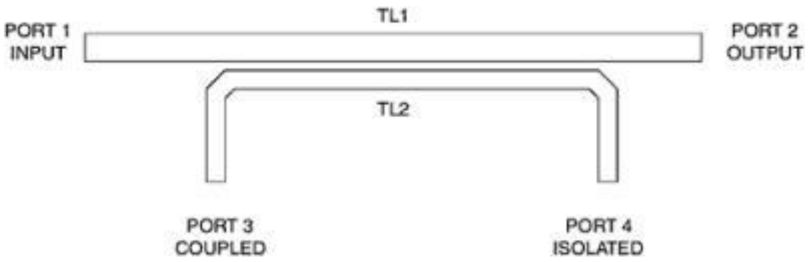
	tion (1) $$P_r = \frac{P_t\, G\, A\, A_R}{(4\pi R^2)^2}$$ $$\therefore\ S_{min} = \frac{P_t\, G\, A\, A_R}{(4\pi)^2 \left(R^2_{max} \right)^2}$$	
Ans: d	State four advantages of geo-stationary satellite. (1 mark each) • Satellite communication links are unaffected by Doppler's shift in frequency. • Three satellites gives global coverage with the exception of the polar regions. • It requires limited earth station tracking since the satellite remains fixed in its position with respect to the earth. • The communication channel can be either broadcast or point to point. • This orbit is sunlit 99% of the time	**4**
B a)	Attempt **any one :** • What is multihole directional coupler ? With neat constructional diagram explain working of multihole directional coupler. Where it is used ? sol: Directional couplers are devices that will pass signal across one path while passing a much smaller signal along another path. One of the most common uses of the directional coupler is to sample a RF power signal either for controlling transmitter output power level or for measurement. An example of the latter use is to connect a digital frequency counter to the low-level port and the transmitter and antenna to the straight-through (high-power) ports. The circuit symbol for a directional coupler is shown in Fig. below. Note that there are three outputs and one input. The IN OUT path is low-loss and is the principal path between the signal source and the load. The coupled output is a sample of the forward path while the isolated showed very low signal. If the IN and OUT are reversed then the roles of the coupled and isolated ports also reversed.	**8** **2+2+2+2**



Directional coupler circuit symbol

An implementation of this circuit using transmission line segments is shown in Fig. below Each transmission line segment (TL $_1$ and TL $_2$) has a characteristic impedance, Z_o, and is a quarter-wavelength long. The path from port 1 to port 2 is the low-loss signal direction. If power flows in this direction, then port 3 is the coupled port and port 4 is isolated. If the power flow direction reverses (port 2 to port 1) then the respective roles of port 3 and port 4 are reversed.



Applications: (Any two)

- measure incident and reflected power to determine VSWR,
- signal sampling,
- signal injection,
- signal generator/oscillator leveling,

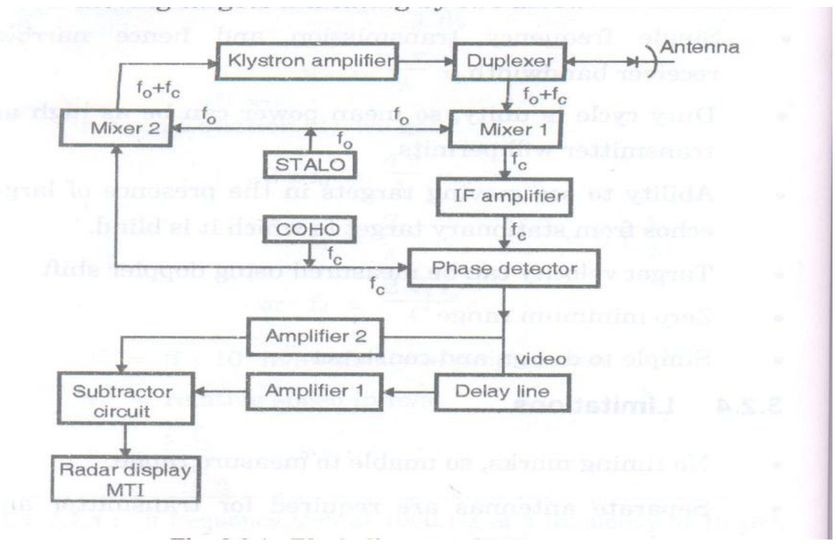
and power flow monitoring

b)

- Sketch block diagram of MTI RADAR. State functions of each block. 4M each

4+4

Block diagram:



Working principle:

- The echo pulse from the target is received by MTI radar antenna.
- If echo is due to moving target, the echo pulse under goes a Doppler frequency.
- The received echo pulses than pass through mixer 1 of the receiver.
- Mixer 1 heterodynes the received signal of frequency (Fo+Fc) with the output of the stalo at Fo.
- Mixer 1 produces a difference frequency Fc at its output.
- This difference frequency signal is amplified by an IF amplifier.
- Amplifies output is given to phase detector.
- The detector compares to IF amplifier with reference signal from the COHO oscillator.
- The frequency produced by COHO is same as IF frequency so called coherent frequency.
- The detector provides an output which depends upon the phase difference between the two signals.
- Since all received signal pulses will have a phase difference compared with the transmitted pulse.
- The phase detector gives output for both fixed and also moving targets.
- Phase difference is constant for all fixed targets but varies for moving targets.
- Doppler frequency shift causes this variation in the phase difference.
- A change of half cycle in Doppler shift would cause an output of opposite polarity in the phase detector output.
- The output of phase detector will have an output different in magnitude and polarity fro successive pulse in case of moving targets.
- And fro fixed target magnitude and polarity of output will remain the same as shown in figure.

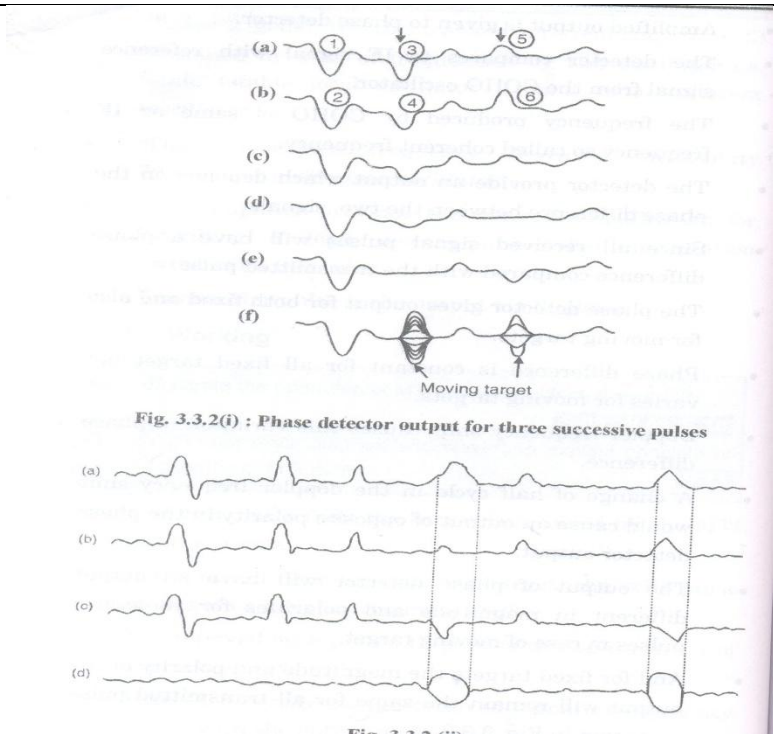


Fig. 3.3.2(i) : Phase detector output for three successive pulses

2 a) . Attempt **any four:** **16**

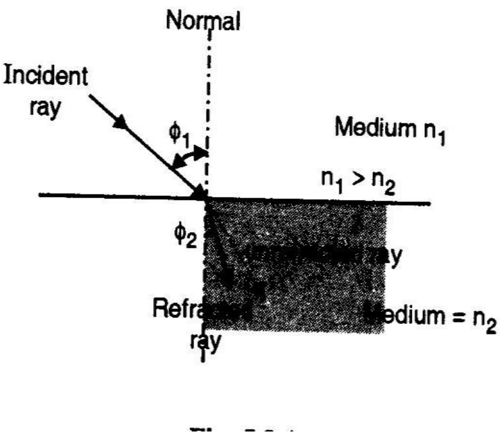
- State Snell's law: Define numerical aperture and critical angle. **2+1+1**

Snell's law states that if the dielectric on the outer side of the interface has a refractive index n_2 which is less than n_1, then refraction is such a way that the ray path in lower index medium is at angle Ør to the normal

$$n_1 \sin \phi_i = n_2 \sin \phi_r$$

or

$$\frac{\sin \phi_1}{\sin \phi_2} = \frac{n_2}{n_1}$$



b)	Numerical aperture: numerical aperture is the measure of light capturing capability of a fiber. It is independent of fiber core diameter.2M Critical angle: It is a angle of incidence at which the refracted ray emerges parallel to the interface between two different dielectrics. • Compare wave guide with two wire transmission line (any four factors). 1M each Sol: Similarities: • Wave travelling in the waveguide has a phase velocity and will be attenuated as in transmission line. • When the wave reaches end of the waveguide it is reflected unless the load impedance is adjusted to absorb the wave. • Any irregularity in wave guide produces reflection just like an irregularity in the transmission line. • When both incident and reflected wave are present in a waveguide a standing wave pattern is generated as in transmission line. Dissimilarities: • There is cut off value of frequency of transmission depending on the dimension of shape and waveguide. Only wave having frequency greater than cut off frequency will be propagated. Hence waveguide acts as a high pass filter with Fc(cut off frequency). In 2 wire lossless transmission line all the frequency can pass through. • Waveguide is one conductor transmission system, the whole body of the waveguide acts as a ground and wave propogates through multiple reflection from walls of waveguide. • The velocity of propagation of waves inside the waveguide is quite different from that through free space due to multiple reflections from the walls of waveguide. • In waveguide, wave impedance which is analogous to the characteristics impedance Zo of 2 wire transmission system.	4

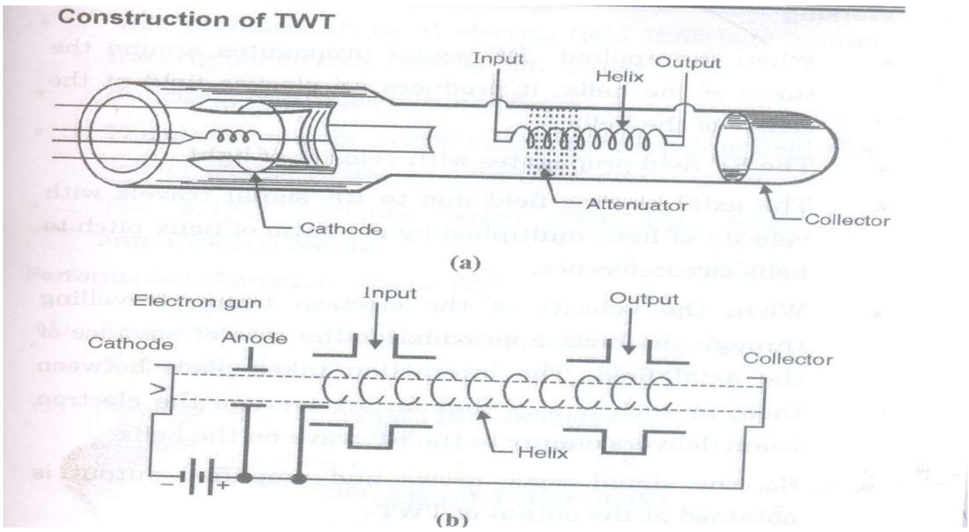
- The system of propagation in a waveguide is in accordance with field theory while that in transmission line is in accordance with the circuit theory.
- If one of the end of the waveguide is closed using a shorting plate, there will be a reflection and hence standing waves will be formed. In other hand if the other end is also closed, then the hollow box so formed can support a signal which can bounce back and forth between two shorting plates resulting in resonance.

c)

- Sketch and label constructional diagram of travelling wave tube and state its working principle.

2+2

Sol: constructional diagram:

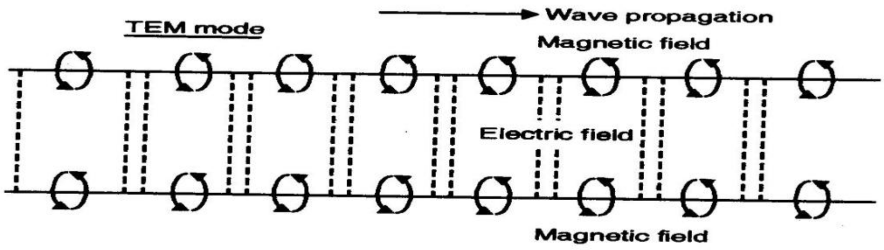


Working principle:

- When the applied RF signal propagates around the turn of helix it produces electric field at the centre of helix.
- The RF field propagates with velocity of light.
- The axial electric field due to the RF signal travels with velocity of light multipled by the ratio of helix pitch to helix circumference.
- When the velocity of electron beams, travelling through the helix approximates the rate of advance of axial field.the interaction takes place between them in such a way that on average the electron beam delivers energy to the RF field in helix.
- So the signal wave grows and amplified output is obtained at output of TWT.
- At a point where axial field is zero electron velocity is unaffected.
- A point where the axial field is positive, the electron coming against it is accelerated and tries to catch up with later electrons which encounter the RF axial field.
- A point where axial field is negative the electrons get velocity modulated.

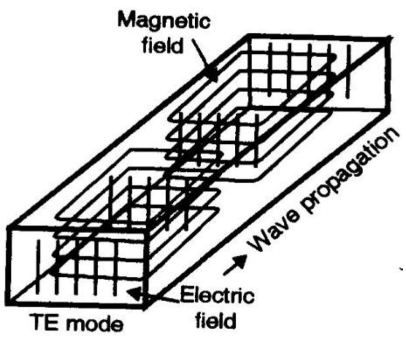
	• And the energy transfer from electron to RF field at axial and second wave is induced on helix. • This produces an axial electric field that lags behind original electric field by $\lambda/4$. • Bunching continues to take place. • The electron in bunch encounter retarding field and deliver energy to way on helix. • The output becomes larger then the input and then amplification results.	
d)	State advantages and disadvantages of continuous wave RADAR (Each two) 1M each Advantages : • Single frequency transmission and hence narrow receiver bandwidth . • Duty cycle is unity, so mean power can be as high as transmitter will permits. • Ability to see moving targets in presence of large number of echoes from stationary target to which it is blind. • Target velocity can be measured using Doppler shift. • Zero minimum range. • Simple to design and construct. Disadvantages: • No timing marks, so unable to measure range. • Separate antennas are required for receiver and transmitter. • Cannot detect targets crossing its beam at right angles.	2+2
e)	What is circulator and isolator? State their functions. 2M each Sol:Circulators • Circulator is 4 port microwave device. • It has peculiar property that each terminal is connected to next clockwise terminals. • That means port 1 is connected to port 2 only and not to port 3 and port4. • Most commonly used circulator is four port circulator. • Circulators are used in parametric amplifiers, tunnel diode amplifiers and duplexers in radars. • It uses property of faradays rotation in the ferrite material. Isolators: • It is a two port device.	2+2

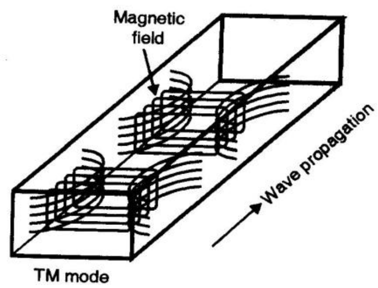
	• It provides very small attenuation for transmission from port 1 to 2 . • But provides very high attenuation for transmission from port 2 to 1. • In most microwave generator the output amplitude tends to fluctuate with change in load impedance. • Fluctuations occur due to mismatch of generator output to load that results reflected wave from load. • That reflected wave causes in stability of amplitude and frequency of microwave generator. • If isolator is inserted between generator and load then generator is connected to load with zero attenuation and reflection. • If any reflection generated from load side than those are completely absorbed by isolator without affecting generator output. • Therefore generator appears to be matched for all loads.	
3) a)	Attempt **any four :** • State the meaning of TEM, TE, TM and HE waves. TEM Mode: All electromagnetic waves consists of electric and magnetic fields propagating in same direction of travel, but perpendicular to each other. In normal transmission line, along the length of line, both electric and magnetic fields are perpendicular to the direction of wave travel this is known as principle mode TEM mode. For TEM wave, $E_z = 0$ and $H_z = 0$. Therefore all the fields components along x and y direction that is E_x, E_y, H_x and H_y vanish and A TEM wave can not exist inside a wave guide	16 1+1+1+1



It is the dominant mode of wave propagation where the cross sectional dimensions of the transmission line are small compares to the wavelength of signal.

TE/TM mode





When an electromagnetic wave propagates down a hollow tube , only one of the field either electric or magnetic will be transverse to the direction of wave of propagation and other fields will loop longitudinally to the direction of travel, but still perpendicular to other field.

- Whichever field remains perpendicular to the direction of travel determines whether the wave propagates in TE or TM mode
- In TE mode electric field remains perpendicular to the direction of travel or propagation
- In TE mode Hz != 0 and Ez=0 if Z is the direction of propagation then no electric line is in the direction of propagation
- In TEM mode magnetic field remains perpendicular to the direction of travel or propagation.
- In TM mode Hz = 0, Ez !=0, if Z is the direction of

propagation the magnetic line is in the direction of propagation.

HE mode:

If both fields Ez and Hz are non zero. If these fields exist, the mode would neither be transverse electric nor transverse magnetic. Then the mode is called as hybrid mode. These modes are designated as HE_{vm} modes.

Where m = mode corresponds to m^{th} root of characteristic equation of hybrid mode

V= integer value

- HE_{11} mode is the dominant mode of circular dielectric of waveguide. For eg optical fibre
- The mode doesn't have any cut off frequency.
- Therefore this is the mode through which the transmission of light takes place inside a single mode optical fibre for 100's of kilometer.

b)	• Explain the concept of dominant mode.	4

- Dominant mode is that mode for which cut off wavelength (λc) assumes a maximum value.

$$\lambda_{cmn} = \frac{2ab}{\sqrt{m^2 b^2 + n^2 a^2}}$$

$$\text{For } TE_{01} \text{ mode} = \lambda_{c01} = \frac{2ab}{\sqrt{a^2}} = 2b$$

$$\text{For } TE_{10} \text{ mode} = \lambda_{c10} = \frac{2ab}{\sqrt{b^2}} = 2a$$

$$\text{For } TE_{11} \text{ mode} = \lambda_{c11} = \frac{2ab}{\sqrt{a^2 + b^2}}$$

- Of these λ_{c10} has the maximum value since 'a' is the larger dimension. Hence the TE_{10} mode is the dominant mode in the rectangular wave guide.
- Assume the walls of waveguide nearly perfect conductors.
- Therefore electric field will be normal to waveguide walls and magnetic field will be tangential or parallel to wall of waveguides walls.
- Hence zero subscript can exist in TE mode but not in TM mode i.e TE_{10}, TE_{01}, TE_{20} etc modes can exist in rectangular waveguide but only TM_{11}, TM_{12},TM_{21} etc modes can exist.
- The physical size of waveguide determines the propagation of modes depending on the values of m and n.
- The minimum cut off frequency of rectangular waveguide is obtained for a dimension. a>b for m=1 and n=0 that is TE_{10}.

- Sum of the higher order modes, having same cut off frequency are called degenerate modes.
- For a rectangular wave guide TE_{mn}/TM_{mn} modes for which m is not equal to zero, and n is not equal to zero will also be degenerate mode.
- For square guide in which a=b all modes TE_{pq}, TE_{qp}. TM_{pq}. TM_{qp} modes are together degenerate mode.
- To avoid undesirable components appearing at the output along with losses higher order degenerate mode are not supported by the guide in the operating band of frequencies.
- It is also necessary to prevent the conversion of particular waveguide mode to another.
- More conversion results from irregularities etc.
- Hence chose suitable waveguide dimensions or use waveguide with mode filters.
- The various modes in a waveguide can be excited by various launching devices like antenna.

c) Compare LED and LASER diode (any four factors). 4

Sr no	Parameter	LED	Laser
1	Data rate	Low	Very high
2	Cost	Low	High
3	Noise	More	Less
4	Principle of operation	Spontaneous emission	Stimulated emission

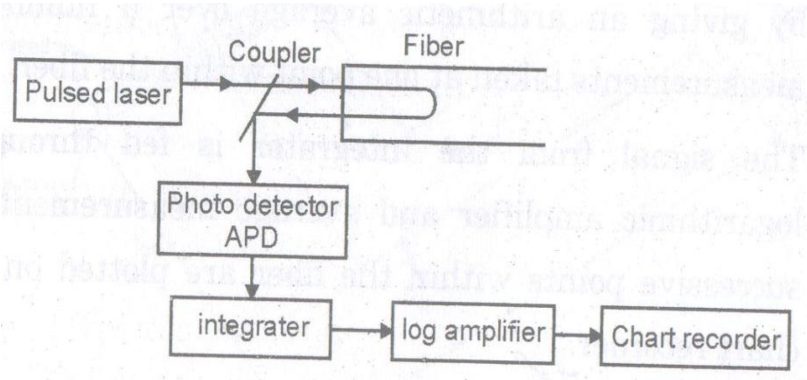
d)
- State working of OTDR with block diagram. 4

2M each

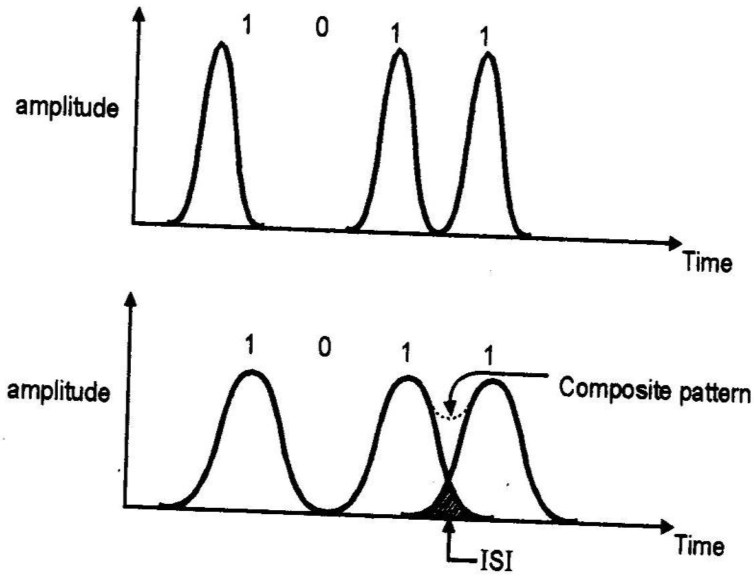
Sol:

- An optical time domain reflector is used in fiber optics to measure the time and intensity of light reflected on an optical fiber.
- It is used as trouble shooting device to find faults, splices and bends in fiber optic cables with an eye towards identifying light loss.
- Light loss is important in fiber optic cables because it can interface with the transmission of data.
- An OTDR can detect such light loss and pinpoint trouble areas making repair easy.
- The more quickly trouble areas are identifies and addressed the less fiber optic network will suffer from data transfer problems.

- An OTDR test can anywhere along the length of fiber from ten seconds to three minutes.
- It emits a high power pulse that hits the fiber and bounces back.
- What comes back is measured, factoring in time and distance and results in "trouble spots" which radiate and can be targeted for repair.
- Some OTDR systems are equipped with PC-linking capabilities that the data recorded during testing can be downloaded to a computer for analysis and storage.



- The above figure is the block diagram.
- The main blocks of the reflectometer are the generator of the testing impulse and detection system of the backscattered light.
- The remaining blocks provide the suitable timing of signals and the interpretation of the measured data(display)
- 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.
- Integrator improves the received signal to noise ratio by giving an arithmetic receiver over a number of measurements taken at one point within the fiber.
- The signal from the integrator is fed through a log amplifier and average measurements for successive points within the fiber are plotted on as a chart recorder.
- Figure shows the possible back scatter plot from fiber under test.
- A long tail caused by the distributed Raleigh scattering from

	the input pulse as it travels down the link. • In plot there is a pulse corresponding to the discrete reflection from fiber joint excessive loss at fiber imperfections. • The end of fiber link is indicated by pulse corresponding to Fresnel reflection. • From a plot, by calculating the slope of a curve over the length required are can calculate the attenuation unit length for the fiber • Overall link length can be determined from the time difference between the reflection from the fiber input and output end faces	
e)	What is intermodal and intermodel dispersion?  INTRAMODAL: • Intra modal dispersion is also called chromatic dispersion. • It occurs in all types of optical fibers. • It results from the finite spectral line width of the optical source. • We know that optical sources do not just emit just a single frequency but band of frequencies. • There may be propagation delay differences between the different spectral components of the transmitted signals. • Delay in propagation causes broadening of each transmitted mode and so called intra modal dispersion. • This delay may be caused by the dispersive properties of waveguide and the fiber structure. • Delay due to waveguide material is called material dispersion.	2+2

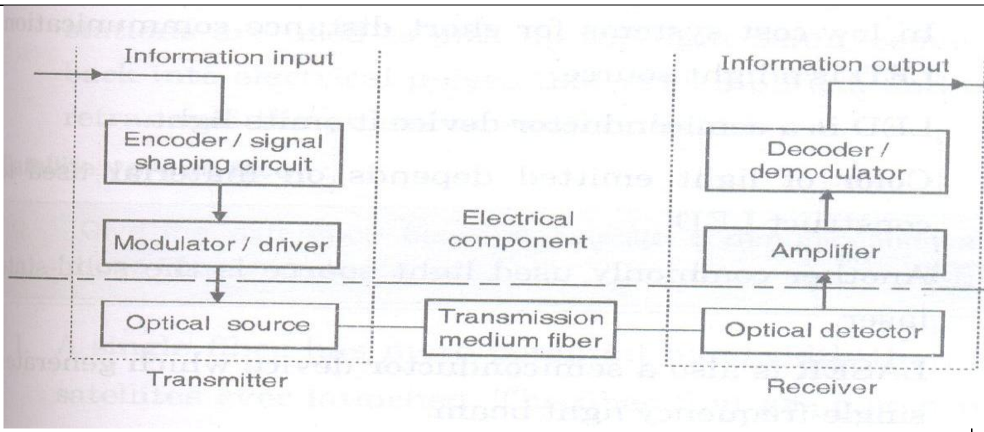
- Delay due to fiber structure is called waveguide dispersion.
- The types are 1. Material dispersion 2. Waveguide dispersion

INTERMODAL:

- It results from the propagation delay difference between modes within a multimode fiber travel along the channel with different group velocities.
- The pulse width at output is dependent upon the transmission times of slowest and fastest modes.
- Multimode step index fibers exhibit a large amount of intermodal dispersion.
- In multimode graded index fibers is far less than that obtained in multimode step index fibers.
- In multimode step index, the fastest and slowest modes propagating in it may be represented by axial ray and the extreme meridional ray respectively.
- The delay difference between these two rays when travelling in the fiber core allows estimation of the pulse broadening i.e intermodal dispersion.
- It may be reduced by propagation mechanisms within practical fibers
- The differential attenuation of modes reduces intermodal dispersion.
- Mode coupling or mixing reduces the intermodal dispersion.
- The coupling between guided modes transfers optical power from the slower to fastest modes and vice versa.
- Strongly coupled, optical power transmits at an average speed i.e mean of various propagating modes.
- Intermodal dispersion in multimode fiber is minimized by using graded index fiber.
- In above figure meridoinal rays follow sinusoidal trajectories of different path lengths which results from the index grading.
- The group velocity is inversely proportional to the refractive index.
- The longer sinusoidal paths are compensated for by higher speed in the lower index medium away from axis.
- Rays travel in the high index region at core axis at the slowest speed.
- Various ray paths represent the different modes propagating in the fiber.

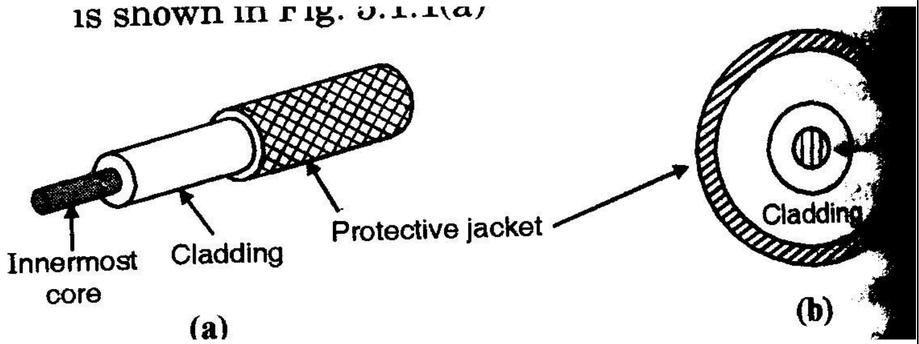
The graded profile reduces in the mode transmit time

4 A) a) b)	Attempt **any two :** • What is RADAR Beacon? How it operates? Sol: • RA-dar bea-CONS also called as radar responders or transponders.. • RACONS are receiver/transmitters. • This device is used as navigation aid, identifying land marks. • Racon responds to a received radar pulse by transmitting an identifiable mark back to radar set. • Racons are used for following purpose • To identify aids to navigation both seaborne and land based. • To identify land full. • To indicate navigable spans under the bridges. • To identify offshore oil platforms. • To identify and warn of environmentally sensitive areas. • To identify centers and turning points. • To mark a uncharted hazards. • All racons operate at frequency range of 9300 to 9500MHz and 2900-3100 Mhz • Racons range is approximately line of site range • Racon range depends upon a number of factors including mounting height, atmospheric conditions and racon receiver sensitivity setting. • Modern racon have wide band receiver that detects the incoming radar pulse, turns the transmitter and responds with 25µsecs long signal within 700nsec. • Older racons operates in a slow sleep mode (x'ponder sweeps across the x-band over 1 or 2 minutes). • It only responds only if the frequency of an incoming signal at moment it arrives tuned to it. • RACON is a device that on receiving radar signal, transmits coded signals in response to help navigators determine their position. Sketch blocks diagram of fiber optic communication and state functions of each block. 2M each Sol	8 2+2 2+2



Note ;Each block should be explained in detail

c) Draw the constructional sketch of fiber optic cable and give its classification. 2+2



Classification of fibers is as follows;

1 .Step index fibers

i. Single mode

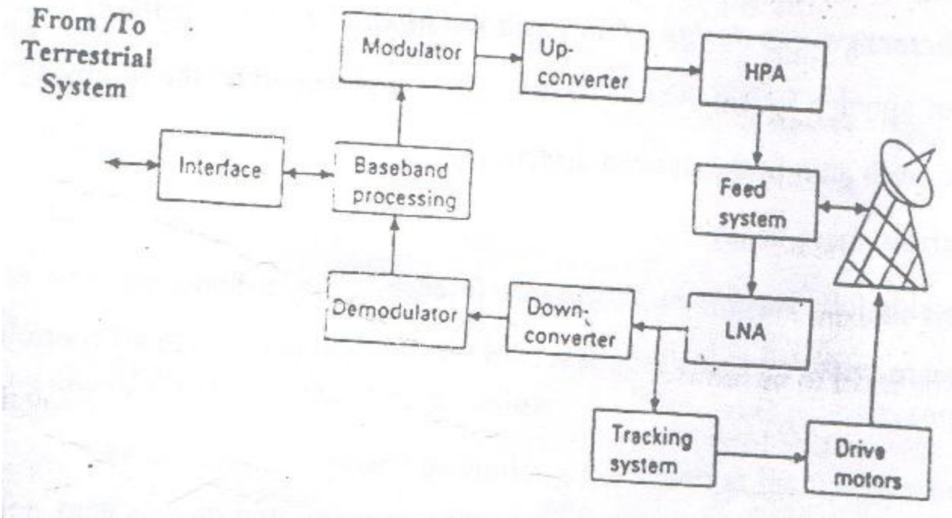
ii. Multimode

2. Graded index

i. Multimode

B) B) Attempt **any one:** 8

a) Sketch block diagram of satellite earth station and state functions of each block. 4+4



Note ;Each block should be explained in detail

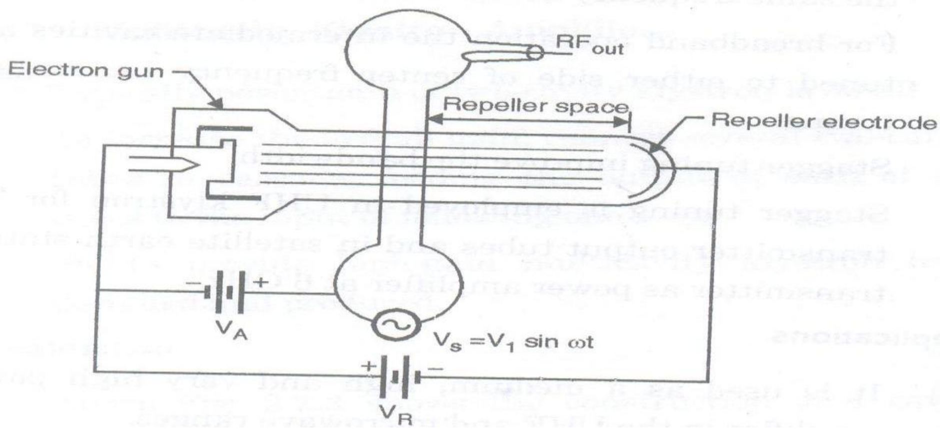
b) | 3+3+2

- With neat constructional diagram explain operation of reflex klystron. State its applications.

  Sol:

  Constructional diagram:

  3M



  Working principle:
  3M

- The electron beam injected from the cathode is velocity modulated by cavity gap voltage.
- Some electrons are accelerated by accelerating field and enter the repeller space with greater velocity than those with unchanged velocity.
- Some electrons decelerated by the retarding field enter the repeller region with less velocity.
- All electrons turned around by the repeller voltage than pass through the cavity gap in bunches that occur once per cycle.
- On the return journey the electrons pass through the gap during retarding phase of the alternating field.
- They give their kinetic energy to electromagnetic energy of field in cavity.

- The electrons are finally collected by walls of cavity.

Applications: (Any two) 2M

- In radar receiver.
- In local oscillators in microwave receivers.
- Signal sources in microwave generator of variable frequency.
- Portable microwave link.

Pump oscillator in parametric amplifier

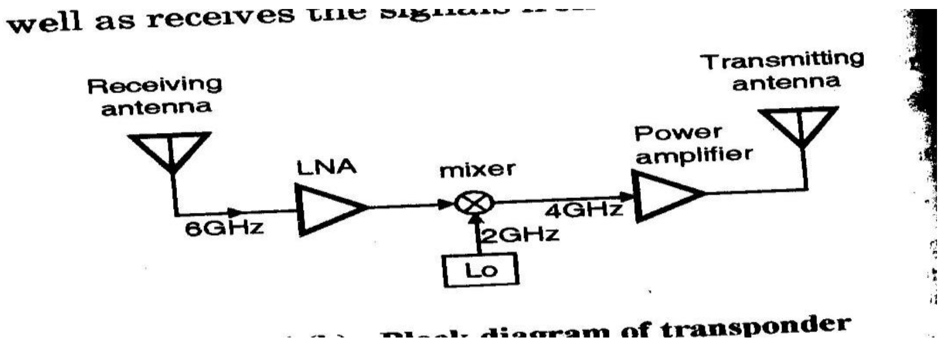
5 Attempt **any four :** 16

a)

- Explain uplink and downlink frequency bands used in satellite communication. 2M each 2+2

Soln:

- The range of frequencies used for satellite communication is from 3-3-GHz i.e. microwave range
- The uplink frequency can be defined as a frequency used by signal transmitted from transmitting earth station towards satellite
- Uplink frequencies are generally higher than the down link
- Generally the frequency band from 5.9 – 6.4 GHz is sued for uplink transmission.
- The downlink frequency can be defined as the frequency of signals which is retransmitted from satellite to earth station.
- Generally the downlink frequencies range between 3.7- 4.2 GHz.
- In the satellite, the signals are down converted to the frequency of downlink.
- In the satellite transponder is a combination of transmitter and receiver which down converts the signals as well as receives the signals from earth station.



- Above figure shows the satellite transponder.

	• Mainly the function of transponder is amplification of signal and frequency translation. • The frequency translation is necessary because transponder cannot transmit and receive on the same frequency. • A satellite is not a passive relay station. • It does not just reflect signals; it receives them, processes them, down converts them and retransmits them. • On board each satellite have a number of transponders. • Transponders not only transmit videos, but also mono and stereo audio, news reports and data. • The average operating power of transponder is 5 watts. • The number of transponder on the satellite is related to bandwidth requirement	
b)	• What is scattering loss ? Which type of scattering losses occur in fiber optic ? Sol : Scattering loss occurs in glass due to microscopic variations in the material density, compositional fluctuations, structural in homogeneities, defects during fiber manufacturing. 1M In fiber optics two types of losses occur 3M • Linear scattering : This mechanism causes the transfer of some or all the optical power contained within one propagating mode linearly into a different mode. This results in attenuation of the transmitted light as leaky or radiation mode without propagation. it is categorized into two types • Rayleigh • Mie • Non linear Scattering : In optical waveguide optical output power is not always proportional to input optical power. At high optical power levels due to non linear effects, scattering causes disproportionate attenuation. Non linear scattering cause the optical power from one mode to be transferred in either the forward or backward direction to the same or other modes at different frequency. The types of Non linear scattering are • Stimulated Brillouin Scattering	1+3

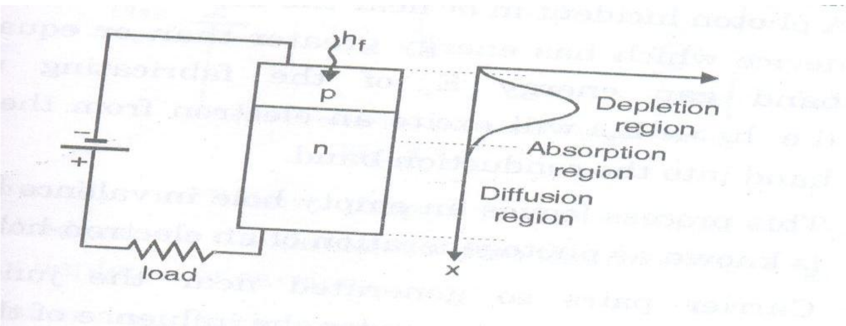
- Raman Scattering

c)

- State the working principle of photodiode. State its limitations. 2+2

2M each

Solution:



- Figure shows reverse biased p-n photodiode with both depletion and diffusion regions.
- The depletion region is formed by immobile positively charged donor atoms in n type semiconductor material and immobile negatively charged acceptors atoms in the p-type material when the mobile carrier are swept to their majority sides under the influence of the electrical field
- The width of depletion region is dependent upon the doping concentrations for a given applied reverse bias.
- Photons may be absorbed in both depletion and diffusion region
- the absorption region's position and width depends , upon the energy of the incident photons and on the material from which the photo diode is formed.

Working principle:

- As shown in the fig. photodiode is reverse biased and electric field is developed across the p-n junction sweeps mobile carriers to their respective majority sides.
- A depletion region is created on either side of junction . that stops the movement of carriers from junction in the opposite direction field.
- A photon incident in or near to the depletion region of this device has energy greater than or equal to the band gap energy Es of the fabricating material(i.e. $h_f >> E_g$) will excite an electron from the valance band in to the conduction band
- This process leaves an empty hole in valence band and is

known as photo generation of an electron hole pair.

- Carrier pairs so generated near junction are separated and swept under the influence of electric field to produce a displacement by current in the external circuit in excess of any reverse leakage current.

Limitations

In addition to excess noise, there are limits to device performance associated with the capacitance, transit times and avalanche multiplication time.The capacitance increases with increasing device area and decreasing thickness. The transit times (both electrons and holes) increase with increasing thickness, implying a tradeoff between capacitance and transit time for performance. The avalanche multiplication time times the gain is given to first order by the gain-bandwidth product, which is a function of the device structure and most especially κ.

d) Compare on the basis of any four factors optical fiber communication with radio wave communication. 1M each — 4

Sr no	Parameter	Optical fiber communication	Radio wave communication
1	Frequency range	Above 300GHz	10 KHz to 300 GHz
2	Medium	Optical fiber	Cable or Space
3	Attenuation	Less	More
4	Data rate and Bandwidth	Larger	Smaller

e) How light signal propagates through optical fiber?

Sol: when a light ray is incident on the interference between two dielectrics of differing refractive indices refraction occurs and it is observed that a small amount of light is also reflected back into the originating dielectric medium.

- Following shows the concept of internal deflection.
- As n1>n2 the angle of refraction is always greater than angle of incidence.
- When the angle of reflection is 90° and the refracted ray emerges parallel to the interface between the dielectric the angle of incidence must be less than 90°. The angle

of incidence is known as critical angle(Øc)

$\sin Øc = n_2 / n_1$

- In above figure total internal reflection occurs at the interface between two dielectric of differing refractive indices when the light is incident on the dielectric of lower index from the dielectric of higher index and angle of incidence of the ray exceeds the critical value.
- As shown in above meridional ray passes through the axis of fiber core.
- Any discontinuities or imperfections at the core-cladding interface would result in refraction rather than total internal reflection, with the loss of light ray into the cladding.

6 . Attempt **any four :** 16

a) a) Sketch and label frequencies of light wave spectrum.

Sol: 4

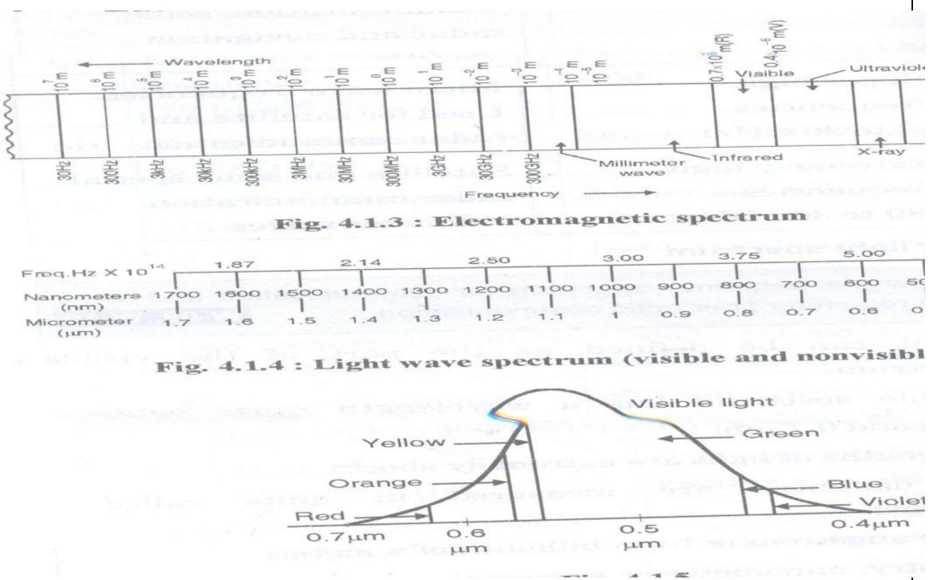
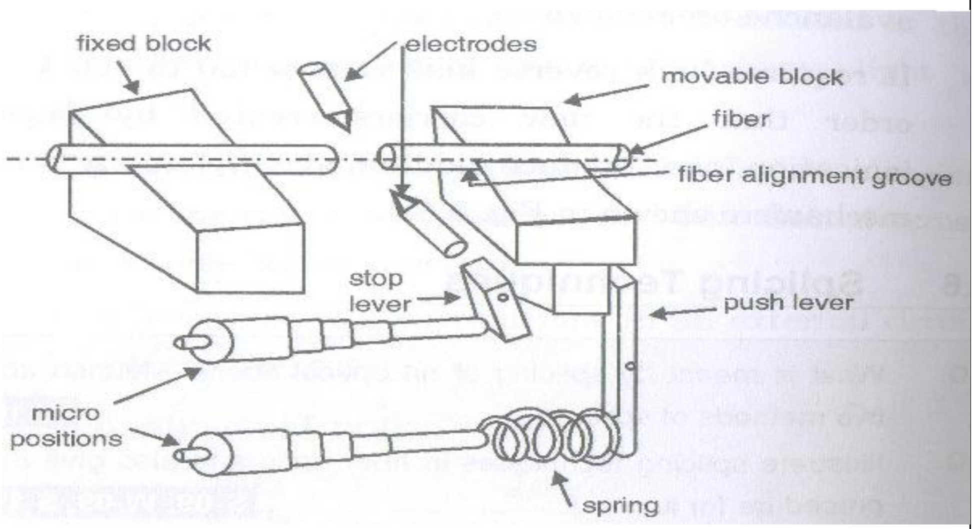


Fig. 4.1.3 : Electromagnetic spectrum

Fig. 4.1.4 : Light wave spectrum (visible and nonvisible)

- The lowest frequencies constitute the radio spectrum.
- Parts of radio spectrum are used for radar.
- Above the radio spectrum, quite narrow visible range with the infrared spectrum is shown. This region is used extensively for remote sensing tools for wide variety of application.
- Above the visible spectrum, ultraviolet spectrum overlapping with X-ray spectrum.

	• The lower part of figure shows the microwave spectrum the portion shown extends from 0.3 to 100 GHz .		
b)	b) Explain in brief splicing technique. 2M each Sol: There are two types of splicing: 1.Fusion splicing or welding 2.Mechanical splicing FUSION splicing • It is accomplished by applying localized heating i.e bi a flame or an electrical arc at a interference between two butted, pre aligned fiber ends. • The figure shown below:  • 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 1. PREFUSION: It is a technique, which involves the rounding of the fiber ends with a low energy discharge before pressing the fibers together. 2. By moving movable block, with proper	2+2	

pressure two fibers are pressed together.

3. Then there will be accomplishment of splice.

Drawbacks of fusion splicing:

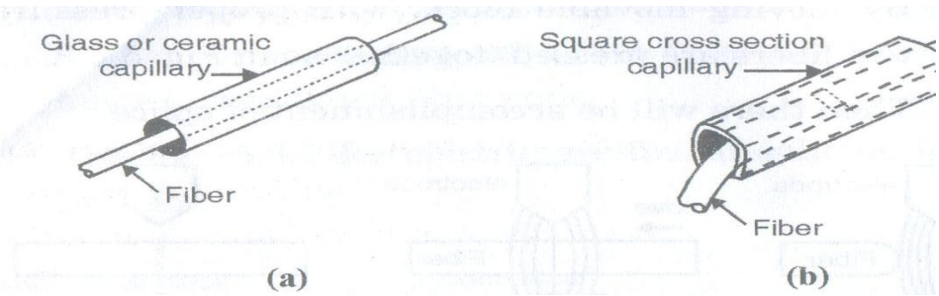
1. Heat necessary to fuse the fibers may weaken then fiber.
2. Possibility of fiber fracture in fused joint.

MECHANICAL splicing

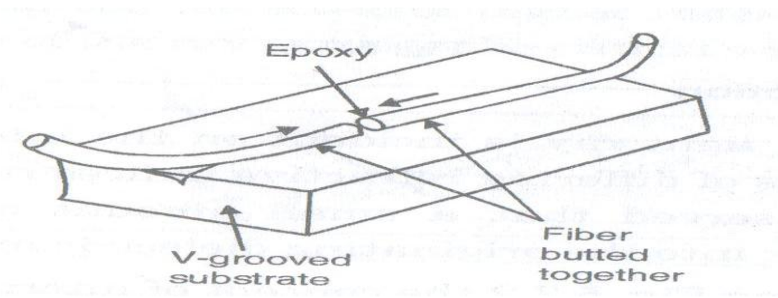
There are number of mechanical splicing techniques.

The common methods are

1. 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.

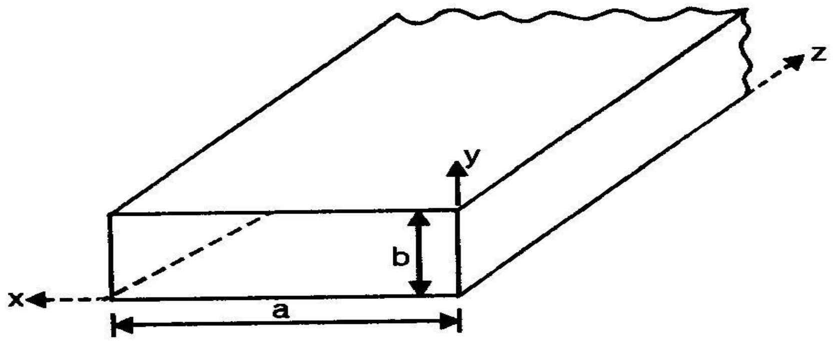


- In snug tune splicing technique uses a glass or ceramic capillary tube with an inner diameter just large enough to accept the optical fibers.
- Transparent adhesive is injected through a transverse bore in capillary to give mechanical sealing and index matching of the splice.
- Average insertion losses 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. Using 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. • Theabove figure shows the technique		
c)	How wave propagation occurs in rectangular waveguide? Sol: • Rectangular waveguide is a hollow metallic tube with a rectangular cross section. • It has width a and height b. • Commonly used rectangular guide has an aspect ratio of 0.5 approx (b/a).	4	

- The physical dimension of waveguide determines the cut off frequency for each mode.
- The walls of waveguide have infinite conductivity and medium is ideal dielectric having permittivity Є, permeability μ and σ=0
- The dominant mode in particular waveguide is the mode having lowest cut off frequency or highest cut off wavelength.
- In a rectangular wave guide TEM mode does not exist

For rectangular wave guide dominant mode is TE_{10} mode



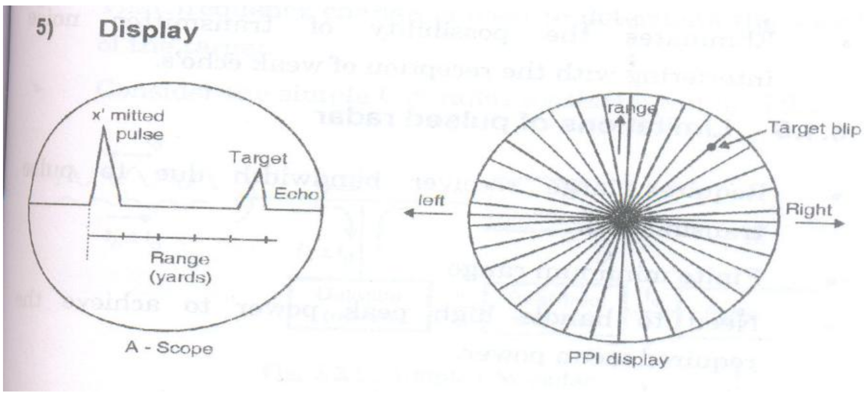
- Above figure shows the direction of propagation of two different electromagnetic wave fronts of different frequencies being radiated into waveguide by a probe.
- The age of incidence and angle of reflection of wave fronts vary in size with the frequencies of the input energy.
- The angle of reflection is equal to each other in waveguide.
- Arrow shows the direction of propagation.
- The cut off frequency in the wave guide is the frequency that causes angles of incidence and reflection to be perpendicular to the wall of guide.
- If the frequency is below the cut off frequency, the wave fronts will be reflected back and forth across the waveband and no energy will be conducted down the waveguide.
- The velocity of propagation of wave along a waveguide is less than its velocity through free space.
- This lower velocity is caused by zigzag path taken by wave front in a waveguide

d) Which type of display methods are used in RADAR system? State features of any one system. — 4

Sol: the display in most radar systems is a cathode ray tube(CRT). Various display formats can be used : 1 A scan 2. PPI

A Scan display:

- The simplest form of display known as A scan, simply displays the transmitted and received pulses.
- The horizontal sweep on the oscilloscope is calibrated in yards or miles shown in figure.



e) State functions of telemetry and tracking system. — 2+2

Sol:

TELEMETRY:

- It collects data from all sensors on the satellite and sends to the controlling earth station.
- The sighting device is used to maintain space craft altitudes are also monitored by telemetry.
- At a controlling earth station using computer telemetry data can be monitored and decoded
- And status of any system on satellite can be determined and can be controlled from earth station.

TRACKING:

- By using velocity and acceleration sensors, on spacecraft the orbital position of satellite can be detect from earth station.
- For accurate and precise result number of earth stations can be used.
