MODEL ANSWER

SUMMER - 2017 EXAMINATION

Subject: Fiber Optic Communication **Subject Code: 17633**

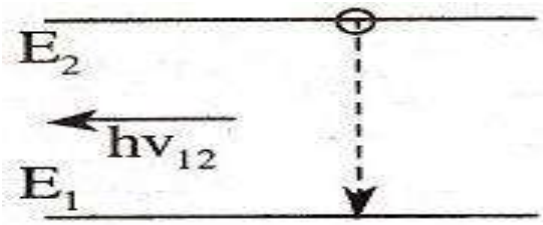
Important Instructions to examiners:

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 moreImportance (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.

Q. No.	Sub Q.N.	Answer	Marking Scheme
1.	**(A)**	**Attempt any THREE of the following:**	**12**
	(a)	**State the advantages of optical fibre communication over conventional communication. (Any Four).**	**4M**
	Ans.	**Advantages of optical fiber communication over conventional communication:** **(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 fibercables do not radiate RF energy and therefore cannot cause interference with other communication system.	***Any four advantages of optical fiber communication over conventional communication 4M***

		(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.	

	(b) Ans.	**Define (i) Refractive index (ii) Critical angle (iii) Numerical aperture (iv) Acceptance angle.** **(i) Refractive index:** The refractive index is the ratio of the velocity of the speed of light in an optical fiber versus the speed of light in a vacuum. The refractive index of the core in an optical fiber must be higher than that of the cladding in order for the transmission of light to be effective. **(ii) Critical angle:** The critical angle (Φc) is defined as the maximum value of angle of incidence up to which the internal reflection will take place. Mathematically the critical angle is $\boldsymbol{\phi_C = \sin^{-1}\frac{\eta_2}{\eta_1}}$ *where η_2 is refractive index of rarer medium and n_1 is refrective index of denser medium* **(iii) Numerical aperture** The numerical aperture (NA) is a measurement of the ability of an optical fiber to capture light. The NA is also used to define the acceptance cone of an optical fiber. $\boldsymbol{NA = \eta_0 \sin\theta_a = (\eta_1{}^2 - \eta_2{}^2)^{\frac{1}{2}}}$ **(iv) Acceptance angle.** The maximum value of the incident angle θa i.e. θa (max) for which the incident light can propagate through the fiber to the far end is called as the acceptance angle. $\sin\theta_{0\max} = n_1\cos\phi_1' = n_1\sqrt{1-\sin^2\phi_1'}$ $= n_1\sqrt{1-\frac{n_2^2}{n_1^2}} = \sqrt{n_1^2 - n_2^2}$	**4M** ***Each definition 1M***
	(c) Ans.	**Draw and explain spontaneous emission and stimulated emission.** **Spontaneous Emission:** Charge carriers are unstable in excited state so they try to come back in stable state and this is possible by emission of radiation. This emission takes place when energy *hv* is released. As it occurs without any external stimulation, it is known as spontaneous emission.	**4M**



Stimulated emission: Here in this type of emission when a photon of energy hv is striking on system while the electron is still in its excited state, then the electron is stimulated so that it drops on to ground state and gives a photon of energy hv n12 and the emitted photon will be in phase with incident photon. The resultant emission is called as stimulated emission.

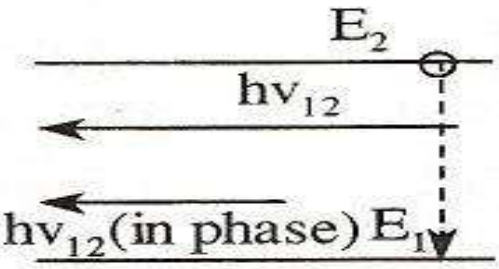


Diagram and explanation 1M each

(d) Ans.

List any four types of fibre connectors with their applications and insertion loss in dB.

Connector types	Applications	Insertion loss
FC	Datacom, telecommunication	0.50 to 1 dB
FDDI	Fiber optic network	0.20 to 0.70 dB
LC	High density interconnection	0.10 to 0.15 dB
MT ARRAY	High density interconnection	0.30 TO 1 dB
SC	datagram	0.20 TO 0.45 dB
ST	Inter/ intra building security, navy	0.40 TO .50 dB

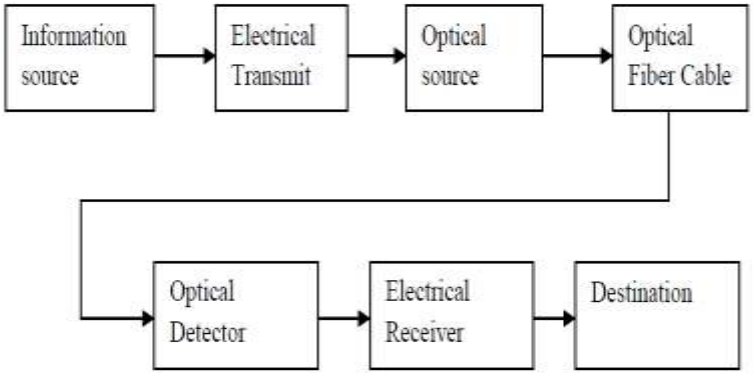
4M

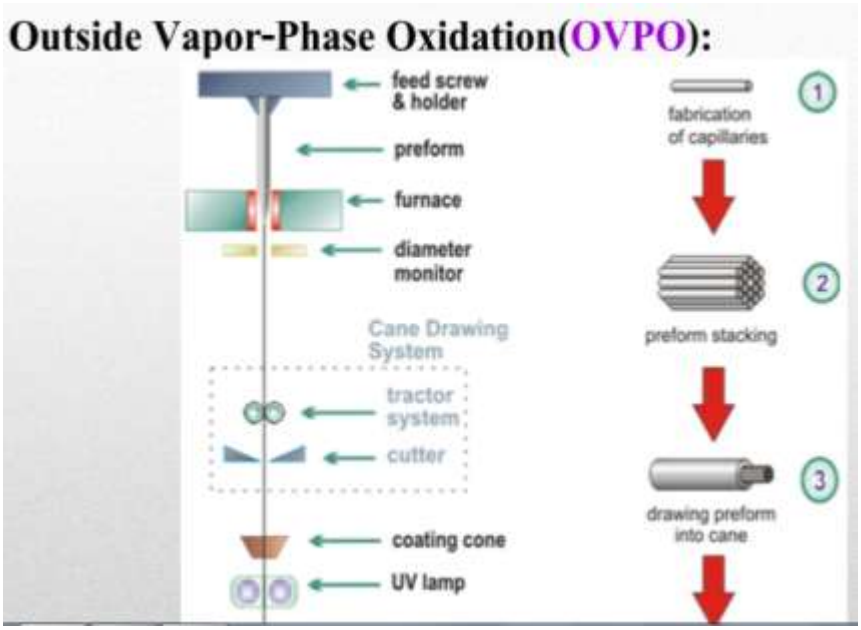
Any 4 types 1M, each , ½M for one application and ½M for insertion loss

1. **(B)** **(a)** Ans.

Attempt any ONE of the following:
Draw the block diagram of fibre optic communication system. Explain in brief the function of each block.

06
6M

		 The information source provides an electrical signal to a transmitter comprising an electrical stage which drives an optical source to give modulation of the light wave carrier. The optical source which provides the electrical optical conversion may be either a semiconductor laser or LED. The transmission medium consists of an optical fiber cable and the receiver consists of an optical detector which drives a future electrical stage and hence provides demodulation of optical carrier. Photo diodes (pn, P-i-N or avalanche) and, in some instances; phototransistor and photoconductors are utilized for the detection of the optical signal and the optical electrical conversion. Thus there is a requirement for electrical interfacing at either end of the optical link and at present the signal processing is usually performed electrically.	***Block diagram 3M*** ***Explanation 3M***
	(b) Ans.	**Name the different techniques of fabricating optical fibres. Explain with neat diagram any one fabrication technique.** **Fiber Fabrication:** 1. Outside Vapor-Phase Oxidation(OVPO) 2. Vapor-Phase Axial Deposition(VAD) 3. Modified Chemical Vapor Deposition(MCVD) 4. Plasma-Activated Chemical Vapor Deposition(PCDV) 5. Photonic Crystal Fiber Fabrication.	**6M** ***Any 3 fiber fabrication 3M***



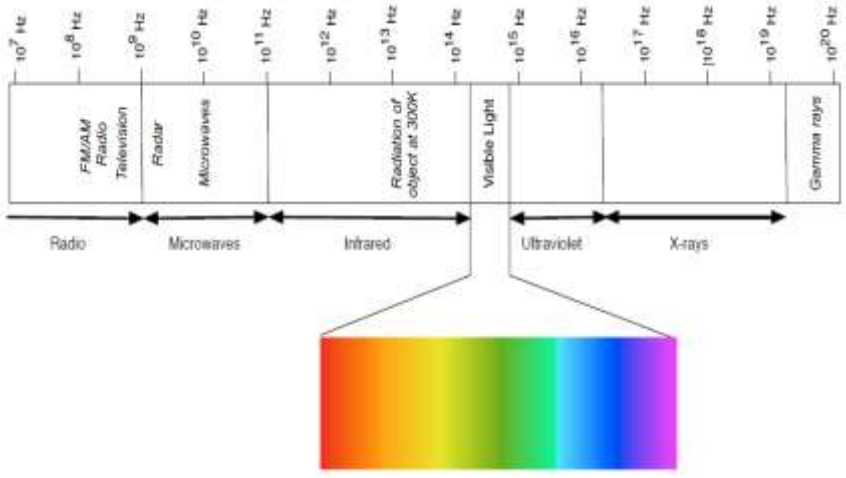
The preform, as mentioned above, is nothing more than an optical fiber but on a much larger scale.
Drawing enables the manufacturer to obtain the fiber in the actual size desired. First a Layer of Sio2 Particles Called a Soot is deposited from a burner onto a Rotating Graphite Or Ceramic Mandrel.

Explain any one techniq ue 3M

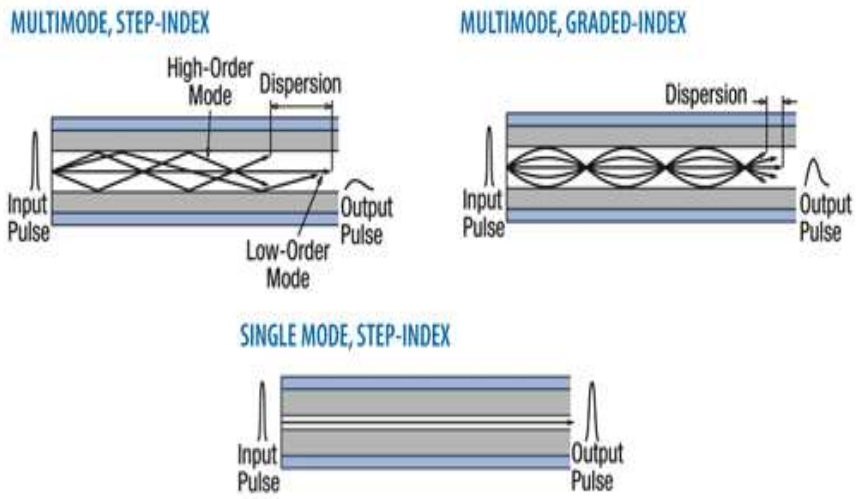
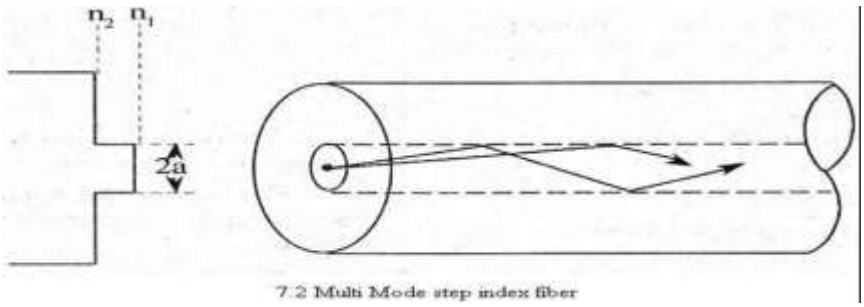
2. **(a)** Ans.

Attempt any FOUR of the following: **16**

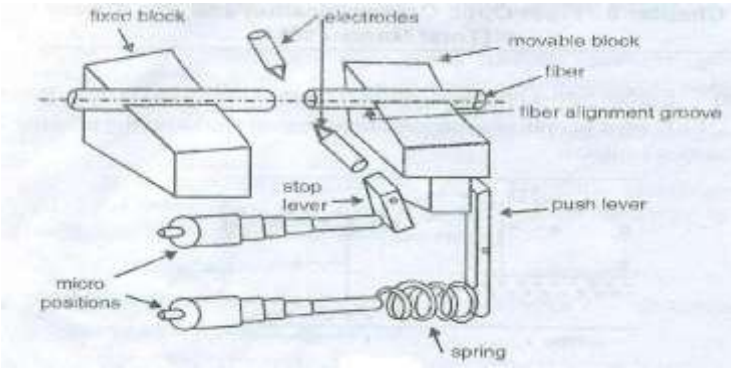
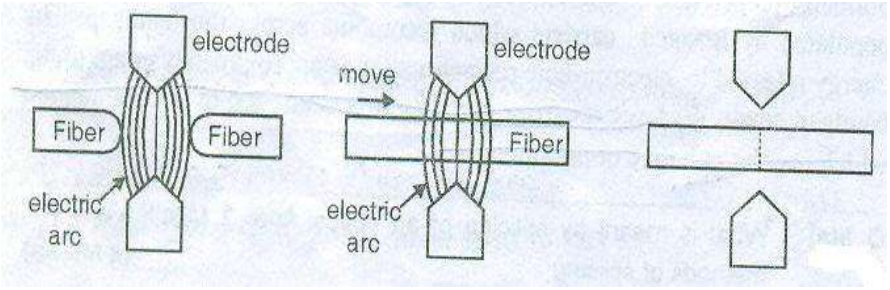
Draw the electromagnetic spectrum showing the region (spectral band) used for optical fibre communication **4M**

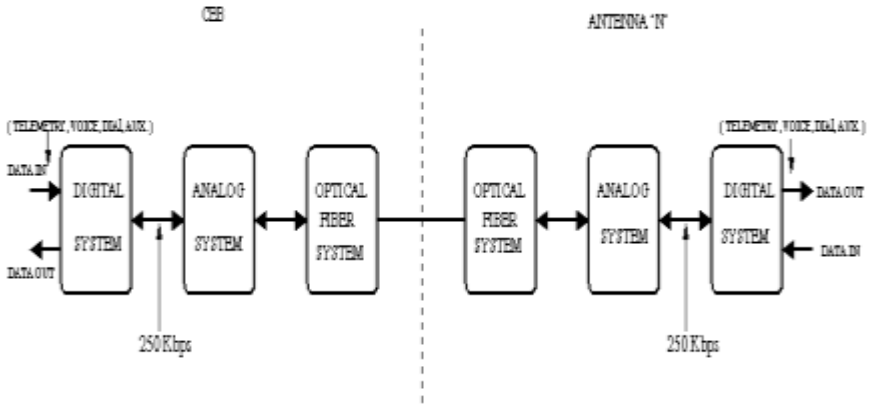


Complet e diagram with all details 4M

	(b) Ans.	**Draw the single-mode step fibre and multi-mode step fibre. Also, state the advantages of multimode fibres over single-mode fibre.**  **Advantages of multi-mode over single-mode:** 1. Multi-mode fiber has higher "light-gathering" capacity than single-mode optical. 2. The larger core size simplifies connections and also allows the use of lower-cost electronics such as light-emitting diodes (LEDs). 3. The limit on speed times distance is lower. 4. Multi-mode fibers have higher numerical apertures which means they are better at collecting light than single-mode fibers.	**4M** ***Multi-mode- any one diagram 1M*** ***Single-mode diagram 1M*** ***Any two advantages each 1M***
	(c) Ans.	**Draw and explain in brief graded index fibres.**  7.2 Multi Mode step index fiber Graded Index Fiber Graded index fiber also contains single mode and multimode. The multimode graded index fiber is shown below, In	**4M** ***Diagram 2M***

		graded index fiber, the refractive index of the core is made to vary as a function of radial distance taken from the center of the fiber. The dimension of its core is 50 to 100 μm and cladding is 125 to 140 μm. In both cases (step index and graded index) multimode has several advantages. When compared with single mode, however, multimode has a drawback, that is, it suffers from inter model dispersion.	***Explanation 2M***
	(d) Ans.	**State the advantages and disadvantages of LED.** **Advantages of LED:** **1. Simple Fabrication:** There are no mirror facets and is some structures no striped geometry **2. Cost:** The simpler construction of LED leas to much reduced cost which is always likely to be maintained. **3. Reliability:** The LED does not exhibit catastrophic degradation and has proved to be less sensitive to gradual degradation than the injection laser. **4. Simpler Drive Circuitry** -This is due to lower drive currents and reduced temperature dependence which makes temperature compensation circuits unnecessary. **Disadvantages of LED:** 1. An LED radiates rather dispersed light, which makes coupling this light into an optical fiber a problem. 2. problems of Absorption	**4M** ***Any two advantages and disadvantages 1M each***
	(e) Ans.	**Explain the fusion splicing technique for joining the optical fibres.** **Fusion splicing:** It is accomplished by applying localized heating i.e. by a flame or an electric arc at the interface between two butted, prealigned fiber ends. The figure for electric arc fusion splicing is shown as below. This technique involves the heating of the 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	**4M** ***Explanation 2M***

		 **OR** Following are the steps for arc 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, as in figure. 2) By moving movable block, with proper pressure two fibers are pressed together as in figure. 3) Then there will be accomplishment of splice. 	***Diagram 2M***
	(f) Ans.	**Draw and explain the block diagram of optical analog systems.** Optical communication is any type of communication in which light is used to carry the signal to the remote end, instead of electrical current. Optical communication relies on optical fibers to carry signals to their destinations. A modulator/demodulator, a transmitter/receiver, a light signal and a transparent channel are the building blocks of the optical communications system. Optical communication systems consist of the following components:	**4M** ***Explanation 2M***

		1. **Transmitter:** Converts and transmits an electronic signal into a light signal. The most commonly used transmitters are semiconductor devices, such as light-emitting diodes (LEDs) and laser diodes. 2. **Receivers:** Typically consist of a photo-detector, which converts light into electricity using the photoelectric effect. The photo detector is typically a semiconductor-based photodiode. 3. **Optical Fiber:** Consists of a core, cladding and a buffer through which the cladding guides the light along the core by using total internal reflection 	***Diagram2M***
3.	**(a)** Ans.	**Attempt any FOUR of the following:** **(a) Define the terms-** **(i) Reflection** **(ii) Refraction** **(ii) Dispersion** **(iv) Polarization of light** **(i) Reflection**: Reflection occurs when a wave hits the interface between two dissimilar media, so that all of or at least part of the wave front returns into the medium from which it originated. **(ii) Refraction: C**hange in direction of propagation of any wave as a result of its travelling at different speeds at different points along the wave front. **(iii) Dispersion:** dispersion is the phenomenon in which the phase velocity of a wave depends on its frequency. Media having this common property may be termed dispersive media.	**16** **4M** ***Each definition 1M***

(iv) Polarization of light: A light wave that is vibrating in more than one plane is referred to as unpolarized light. Polarized light waves are light waves in which the vibrations occur in a single plane. The process of transforming unpolarized light into polarized light is known aspolarization.

(b) Ans. **State the performance characteristics of Laser diode (Any four).** — **4M**

Characteristics of Laser diode:

1. Width of Scan Field
2. Depth of Scan Field
3. Scan Speed
4. Scan Precision
5. Current
6. Angles
7. Working Frequency
8. Communication Distance
9. Communication Interface

Any four characteristics of Laser diode 4M

(c) Ans. **Compare between LED & Laser diode.** — **4M**

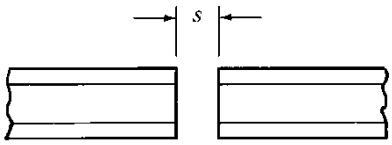
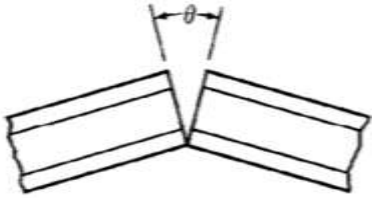
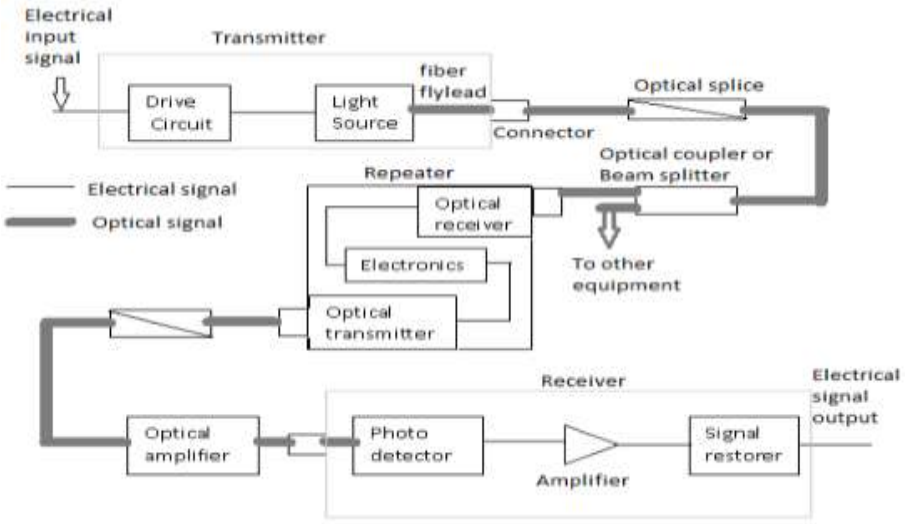
Sr. No.	Parameter	LED	LASER
1	Principle operation	Spontaneous emission	Stimulated emission
2	Output beam	Non-coherent	Coherent
3	Spectral width	Broad (20 – 100 nm)	Narrow (1-5 nm)
4	Data rate	Low	Very high
5	X'mission distance	Smaller	Greater
6	Temperature sensitivity	Less sensitive	More sensitive
7	Coupling efficiency	Very low	High
8	Compatible fibers	Multimode step index	Single mode step index
9	Circuitary	Simple	Complex
10	Lifetime	104 hours	105 hours

Any 4 points 1M each

(d) Ans. **Draw and explain longitudinal and angular misalignments.** — **4M**

Misalignment is the major problem when joining two fibers considering their microscopic size.

A standard multimode GIN fiber core is 50 - 100μm in diameter

		(thickness of the human hair) Single mode fiber has core dia of 9 μm Radiation losses occur because the acceptance cone of the emitting fiber is not equal to the acceptance cone of the receiving fiber. Magnitude of radiation loss depends on the degree of misalignment Three different types of misalignment can occur • Longitudinal Separation • Angular misalignment • Axial displacement or lateral displacement **Longitudinal misalignment:**  **Angular misalignment:**  	***Explanation 2M*** ***Diagram 1M each***
	(e) Ans.	**Draw and explain the block diagram of digital optical system.**  	**4M** ***Diagram 2M***

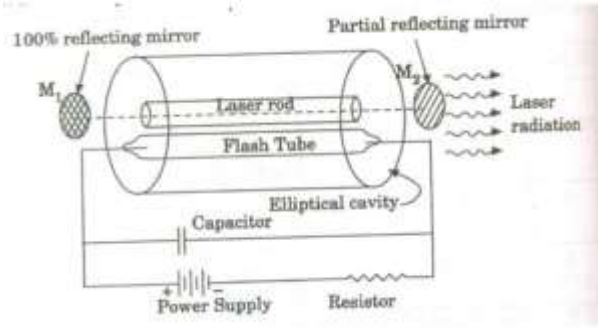
		Explanation- The optical fiber consists of three main elements: 1.Transmitter: An electric signal is applied to the optical transmitter. The optical transmitter consists of driver circuit, light source and fiber fly lead. o Driver circuit drives the light source. o Light source converts electrical signal to optical signal. o Fiber fly lead is used to connect optical signal to optical fiber. 2. Transmission channel: It consists of a cable that provides mechanical and environmental protection to the optical fibers contained inside. Each optical fiber acts as an individual channel. o Optical splice is used to permanently join two individual optical fibers. o Optical connector is for temporary non-fixed joints between two individual optical fibers. o Optical coupler or splitter provides signal to other devices. o Repeater converts the optical signal into electrical signal using optical receiver and passes it to electronic circuit where it is reshaped and amplified as it gets attenuated and distorted with increasing distance because of scattering, absorption and dispersion in waveguides, and this signal is then again converted into optical signal by the optical transmitter. 3. Receiver: Optical signal is applied to the optical receiver. It consists of photo detector, amplifier and signal restorer. o Photo detector converts the optical signal to electrical signal. o Signal restorers and amplifiers are used to improve signal to noise ratio of the signal as there are chances of noise to be introduced in the signal due to the use of photo detectors. • For short distance communication only main elements are required. Source- LED Fiber- Multimode step index fiber Detector- PIN detector • For long distance communication along with the main elements there is need for couplers, beam splitters, repeaters, optical amplifiers. Source- LASER diode Fiber- single mode fiber Detector- Avalanche photo diode (APD)	***Explanation 2M***

4.	**(A)**	**Attempt any THREE of the following:**	**12**
	(a)	**Explain in brief absorption and scattering losses in optical fibres.**	**4M**
	Ans.	**Absorption losses:** Absorption is a major cause of signal loss in an optical fiber. **Absorption** is defined as the portion of attenuation resulting from the conversion of optical power into another energy form, such as heat. Absorption in optical fibers is explained by three factors: 1. Imperfections in the atomic structure of the fiber material 2. The intrinsic or basic fiber-material properties 3. The extrinsic (presence of impurities) fiber-material properties Imperfections in the atomic structure induce absorption by the presence of missing molecules or oxygen defects. Absorption is also induced by the diffusion of hydrogen molecules into the glass fiber. Since intrinsic and extrinsic material properties are the main cause of absorption. **Scattering losses:** Basically, scattering losses are caused by the interaction of light with density fluctuations within a fiber. Density changes are produced when optical fibers are manufactured. During manufacturing, regions of higher and lower molecular density areas, relative to the average density of the fiber, are created. Light traveling through the fiber interacts with the density area. Light is then partially scattered in all directions. Rayleigh scattering is the main loss mechanism between the ultraviolet and infrared regions. **Rayleigh scattering** occurs when the size of the density fluctuation (fiber defect) is less than one-tenth of the operating wavelength of light. Loss caused by Rayleigh scattering is proportional to the fourth power of the wavelength (1/λ4). As the wavelength increases, the loss caused by Rayleigh scattering decreases. **Mie scattering-**If the size of the defect is greater than one-tenth of the wavelength of light, the scattering mechanism is called **Mie scattering**. Mie scattering, caused by these large defects in the fiber core, scatters light out of the fiber core. However, in commercial fibers, the effects of Mie scattering are insignificant. Optical fibers are manufactured with very few large defects.	***2M each for losses explanation***
	(b)	**Explain with neat diagram the working principle of YAG Laser.**	**4M**
	Ans.	YAG laser is a neodymium based laser. Nd stands for Neodymium (rare earth element) and YAG stands for Yttrium Aluminum Garnet	

(Y3Al5 O12) . It is a four level solid state laser.

Construction: The construction of Nd: YAG laser is as shown in the figure 2.17. A small amount of Yttrium ions (Y3+) is replaced by Neodymium (Nd3+) in the active element of Nd: YAG crystal.

This active element is cut into a cylindrical rod. The ends of the cylindrical rod are highly polished and they are made optically flat and parallel. This cylindrical rod (laser rod) and a pumping source (flash tube) are placed inside a highly (reflecting) elliptical reflector cavity.
The optical resonator is formed by using two external reflecting mirrors. One mirror (M1) is 100% reflecting while the other mirror (M2) is partially reflecting.



Explanation 2M

Diagram 2M

Principle: The active medium Nd: YAG rod is optically pumped by Krypton flash tubes. The Neodymium ions (Nd3+) are raised to excited levels. During the transition from meta stable state to ground state, a laser beam of wavelength 1.064μm is emitted.

(c) Ans. **Compare between fusion splice and mechanical splice.** **4M**

Sr. No.	Fusion splicing	Mechanical splicing
1	Fused with the help of electric arc	Spliced with the help of index matching gel.
2	Two separate fibers are not continuous	Joint are continuous
3	Due to electric arc,the strength of glass core is weaken at the point of splicing which causes	No such problems are encountered in mechanical splicing

Any 4 points 1M each

			losses.	
		4	Two fiber ends are aligned and then fused together	Just a mechanical alignment device
		5	Insertion loss is less.	Insertion loss is higher
		6	better reflectance performance	Comparatively Performance is poor
		7	used for long cable runs	used for shorter, local cable runs
	(d) Ans.	**State the advantages and disadvantages of wave division multiplexing optical fibre communication system**. **Advantages of fiber optics**: 1. **Extremely high bandwidth** – No other cable-based data transmission medium offers the bandwidth that fiber does. 2**. Easy to accomodate increasing bandwidth** – Using many of the recent generations of fiber optic cabling, new equipment can be added to the inert fiber cable that can provide vastly expanded capacity over the originally laid fiber. DWDM, or Dense Wavelength Division Multiplexing, lends fiber optic cabling the ability to turn various wavelengths of light traveling down the fiber on and off at will. These two characteristics of fiber cable enable dynamic network bandwidth provisioning to provide for data traffic spikes and lulls. 3. **Resistance to electromagnetic interference** – Fiber has a very low rate of bit error, as a result of fiber being so resistant to electromagnetic interference. Fiber-optic transmission are virtually noise free. 4. **Early detection of cable damage and secure transmissions** – Fiber provides an extremely secure transmission medium, as there is no way to detect the data being transmitted by "listening in" to the electromagnetic energy "leaking" through the cable, as is possible with traditional, electron-based transmissions. By constantly monitoring an optical network and by carefully measuring the time it takes light to reflect down the fiber, splices in the cable can be easily detected. **Disadvantages of Fiber Optics:** 1. **Installation costs, while dropping, are still high** – Despite the fact that fiber installation costs are dropping by as much as 60% a year, installing fiber optic cabling is still relatively costly. As installation costs decrease, fiber is expanding beyond its original	**4M** ***Any two advantages and disadvantages 1M each***

		realm and major application in the carrier backbone and is moving into the local loop, and through technologies such as FTTx (Fiber To The Home, Premises, etc,) and PONs (Passive Optical networks), enabling subscriber and end user broadband access. 2. **Special test equipment is often required** – The test equipment typically and traditionally used for conventional electron-based networking is of no use in a fiber optic network. Equipment such as an OTDR (Optical Time Domain Reflectometer) is required, and expensive, specialized optical test equipment such as optical probes are needed at most fiber endpoints and connection nexuses in order to properly provide testing of optical fiber. 3. **Susceptibility to physical damage** – Fiber is a small and compact cable, and it is highly susceptible to becoming cut or damaged during installation or construction activities. Because railroads often provide rights-of-way for fiber optic installation, railroad car derailments pose a significant cable damage threat, and these events can disrupt service to large groups of people, as fiber optic cables can provide tremendous data transmission capabilities. Because of this, when fiber optic cabling is chosen as the transmission medium, it is necessary to address restoration, backup and survivability. 4. **Wildlife damage to fiber optic cables** – Many birds, for example, find the Kevlar reinforcing material of fiber cable jackets particularly appealing as nesting material, so they peck at the fiber cable jackets to utilize bits of that material.	
4.	**(B)** **(a)** Ans.	**Attempt any ONE of the following:** **Draw the construction and working of Avalanche photodiode. Also state its merits and demerits.** An avalanche photodiode (APD) is a photodiode that internally amplifies the photocurrent by an avalanche process.. In APDs, a large reverse-bias voltage, typically over 100 volts, is applied across the active region. This voltage causes the electrons initially generated by the incident photons to accelerate as they move through the APD active region. As these electrons collide with other electrons in the semiconductor material, they cause a fraction of them to become part of the photocurrent. This process is known as avalanche multiplication. Avalanche multiplication continues to occur until the electrons move out of the active area of the APD.	**06** **6M** ***Working 2M***

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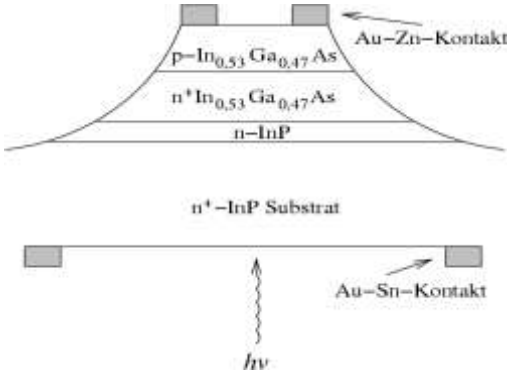
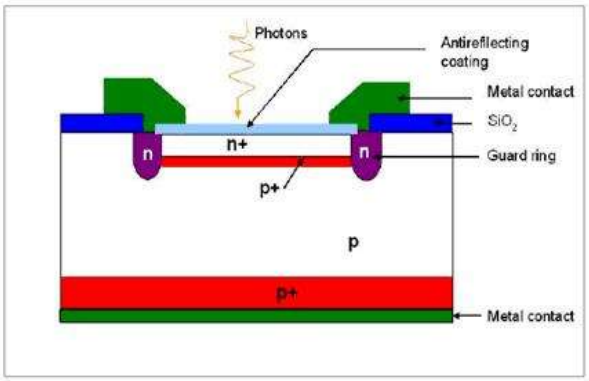
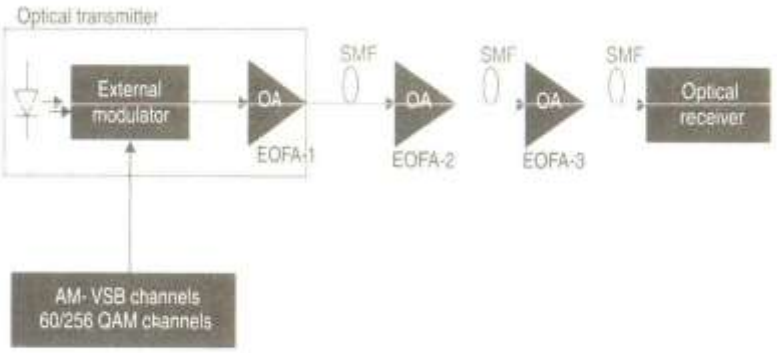
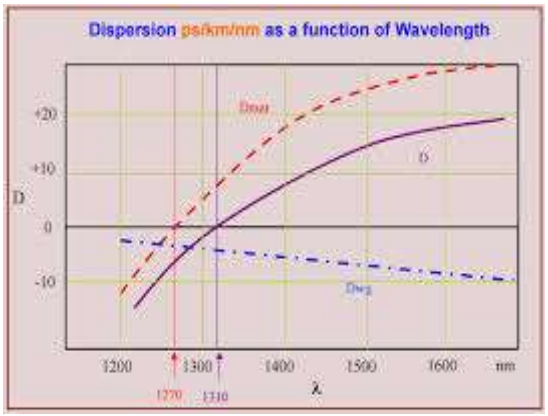
SUMMER - 2017 EXAMINATION

Subject: Fiber Optic Communication **Subject Code: 17633**

		 OR  **Avalanche photodiode merits:** 1. High level of sensitivity as a result of avalanche gain 2. low power consumption, simplicity, high speed. 3. Environmental immunity **Avalanche photodiode demerits:** 1. Much higher operating voltage may be required. 2. Avalanche photodiode produces a much higher level of noise than a PN photodiode 3. Avalanche process means that the output is not linear.	***Diagram 2M*** ***Any 2 merits 1M*** ***Any 2 demerits 1M***
	(b) Ans.	**Draw and explain the under-sea optical systems.** Undersea optical communication means to connect two continents via cable running under the sea. The first transcontinental telegraph cable was installed between North America and Europe. It was intended to provide telegraph service between the two continents. The system operates at the low loss 1550nm wavelength window, with a	**6M** ***Explanation 3M***

		corresponding increase of transmission capacity, to the level of 2.5 Gb/s per fiber, and with a simultaneous increase of the fiber span.  A hybrid multichannel analog and digital video optical link. A block diagram of a typical undersea optical cable system is shown in figure. One of the most important elements in the design of undersea optical links is the incorporation of a performance monitoring mechanism. Such a mechanism is accomplished through high loop back paths between EDFAs. A-45 dB signal identified by a specific delay time is allowed to travel in the opposite direction. At the land terminal, this small signal correlates with the outgoing 5Gb/s signal, and the gain of the loopback path is established by means of a set modulation depth. If the identified modulation depth increases by 100% then the system is out of services.	***Diagram 3M***
5.	**(a)** Ans.	**Attempt any FOUR of the following:** **Draw and explain inter-model dispersion.** **Inter-Modal Dispersion:** The inter-modal dispersion is due to difference in velocity of different modes inside a fiber. The inter-modal dispersion takes place in a multi-mode fiber. the optical rays launched at different angles give different modal fields. The inter-modal dispersion can therefore be approximately calculated using the ray model. The inter-modal dispersion is approximately given as $Dmod = \frac{\delta\ tmod}{L}$ $\delta\ tmod$ =tmax –tmin Difference between higher and fundamental modes time propagation L – Fiber length	**16** **4M** ***Explanation 2M***

		The magnitude of inter-modal dispersion is much larger compared to the chromatic dispersion. Therefore the chromatic dispersion is neglected while calculating the dispersion in a multi-mode fiber 	***Diagram 2M***
	(b) Ans.	**Explain in brief mechanical properties of fibre. (Any Four)** Strength and static fatigue are the two basic mechanical characteristics of glass optical fibers. Since the sight and sound of shattering glass are quite familiar, one intuitively suspects that glass is not a very strong material. However, the longitudinal breaking stress of pristine glass fibers is comparable to that of metal wires. The cohesive bond strength of the constituent atoms of a glass fiber governs its theoretical intrinsic strength. Maximum tensile strengths of 14 GPa (2 X 10^6 lb/in.^{2}) have been observe in the short-gauge length glass fibers. This is close to the 20-GPa tensile strength of steel wire. Another important factor to consider is dynamic fatigue. When an optical cable is being installed in a duct, it experiences repeated stress owing t surging effects. The surging is caused by varying degrees of friction between the optical cable and duct or guiding tool in a man whole on curved route. A high assurance of fiber reliability can be provided by proof testing in this method optical fiber is subjected to tensile load greater than that excepted any time during the cable manufacturing installation and service. Any fibers which do not pass the proof test are rejected.	**4M** ***Any four properties 4M***

MODEL ANSWER

SUMMER - 2017 EXAMINATION

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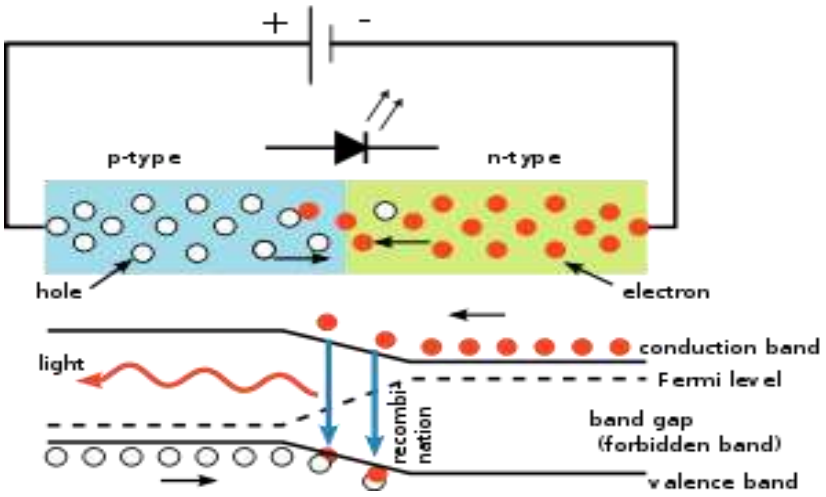
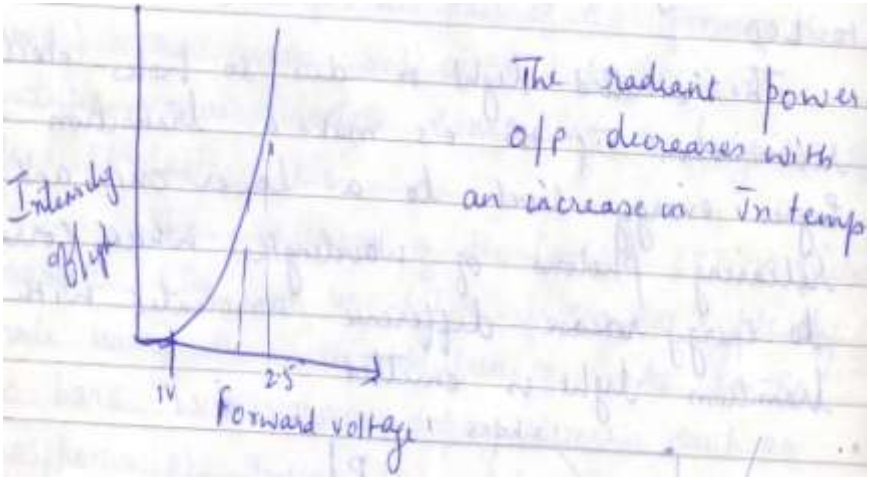
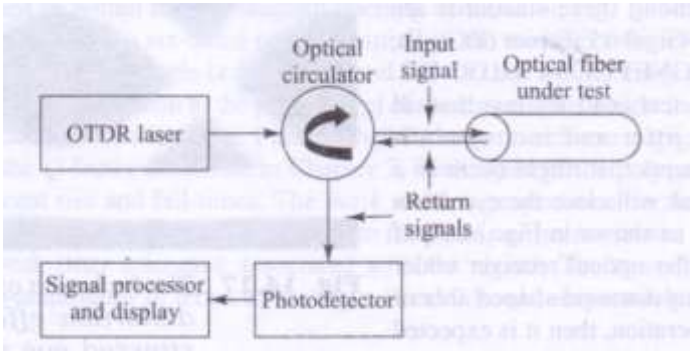
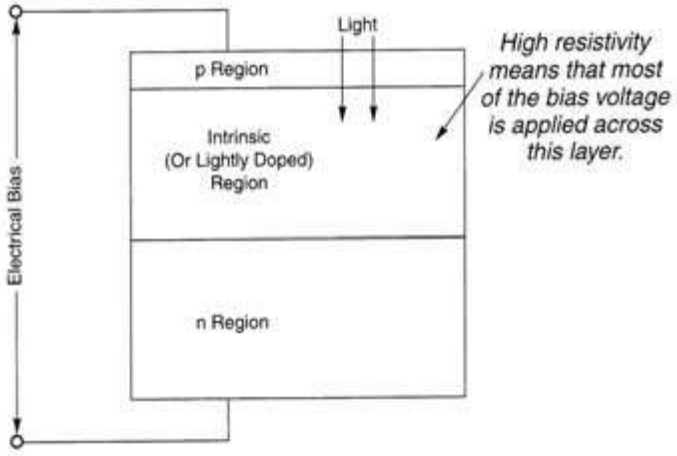
	(c) Ans.	**Explain the terms-** **(i) Responsivity (ii) Dark current** **(i) Responsivity:** The responsivity is a ratio of the output current of the detector to its optic input power, expressed in A/W In equation form, p=i/P **(ii) Dark current:** It is defined as the reverse leakage current of photodetector device in absence of optical power entering the photodetector device.It is unwanted element caused by the factors such as current recombination within the depletion region & surface leakage current.	**4M** ***Each term 2M***
	(d) Ans.	**Explain the working principle of LED and draw its characteristics.**  LED works by the process of spontaneous emission. It is a semiconductor junction diode which emits light when current is passed through it in forward biased condition, one side of the diode is p type so material containing a very large number of holes. The other side of the diode is the n-type semiconductor containing a large no of free conduction electrons. The spectrum of the typical LED is quite broad. LEDs for use with fibers are typically made using a solid solution of GaAs as the base with various doping elements such as Phosphorous (p), Indium (In),	**4M** ***Working principle of LED 2M***

		Al used to form P & N type region. GaAsP. Diodes can be made with band gaps in the range 1.5-2.0 ev The surface layer is P-type.A shallow p-n junction is formed and electrical contacts made to both regions. The upper part of the p-material is left uncovered so that radiation from the devices are not much affected. The inner quantum efficiency of the LED material sometimes 100%.The external efficiency is much lower. Most of the emitted radiation strikes the material interface at an angle which is grater the critical angle. This works out to be expensive in most cases but it is used in high power diodes. The common method is to cover the junction in a transparent medium of high refractive index(about 1.5).By having plastic in the form of a hemisphere, such losses may be made small. **Characteristics:** The radiant power output decreases with an increase in junction temperature.  	***Characteristics 2M***
	(e) Ans.	**Draw and explain the block diagram of Optical Time domed Reflectometer.** **Optical Time domed Reflectometer (OTDR):** An optical time domain reflectometer is a versatile portable instrument that is used widely to evaluate the characteristics of an installed optical fiber link. In addition to identifying and locating faults within link, this instrument measures parameters such as fiber	**4M** ***Explanation 2M***

		attenuation, length, optical connector and splice losses and light reflectance levels. An OTDR is fundamentally optical radar. The OTDR operates by periodically launching narrow laser pulses into one end of a fiber under test by using either a directional coupler or a circulator. The properties of the optical fiber link then are determined by analyzing the amplitude and temporal characteristics of the waveform of the reflected and back scattered light. A typical OTDR consists of a light source and receiver, data-acquisition and processing modules, an information-storage unit for retaining data either in the internal memory or on an external disk and a display. Figure shows a portable OTDR for making measurements in the field.  	***Diagram 2M***
	(f) Ans.	**Explain the concept of synchronous optical networking (SONET).** **Synchronous Optical Networking (SONET):** standardized multiplexing protocols that transfer multiple digital bit streams over optical fiber using lasers or light-emitting diodes (LEDs). Lower data rates can also be transferred via an electrical interface. The method was developed to replace the Plesiochronous Digital Hierarchy (PDH) system for transporting larger amounts of telephone calls and data traffic over the same fiber without synchronization problems. SONET generic criteria are detailed in Telcordia Technologies Generic Requirements document GR-253-CORE.Generic criteria applicable to SONET and other transmission systems (e.g., asynchronous fiber optic systems or digital radio systems) are found in Telcordia GR-499-CORE. SONET originally designed to transport circuit mode	**4M** ***Explanation 4M***

		communications (e.g., DS1, DS3) from a variety of different sources, but they were primarily designed to support real-time, uncompressed, circuit-switched voice encoded in PCM format.The primary difficulty in doing this prior to SONET was that the synchronization sources of these various circuits were different. This meant that each circuit was actually operating at a slightly different rate and with different phase. SONET allowed for the simultaneous transport of many different circuits of differing origin within a single framing protocol. SONET is not itself a communications protocol *per se*, but a transport protocol. Due to SONET is essential protocol neutrality and transport-oriented features, SONET was the obvious choice for transporting Asynchronous Transfer Mode (ATM) frames. It quickly evolved mapping structures and concatenated payload containers to transport ATM connections. In other words, for ATM (and eventually other protocols such as Ethernet), the internal complex structure previously used to transport circuit-oriented connections was removed and replaced with a large and concatenated frame (such as OC-3c) into which ATM cells, IP packets, or Ethernet frames are placed.	
6.	**(a)** Ans.	**Attempt any FOUR of the following:** **Draw the PIN photodiode and state its advantages and disadvantages.** **Diagram of PIN photodiode:**  	**16** **4M** ***Diagram 2M***

<table>
<tr><td></td><td></td><td>Advantages of PIN photodiobe:
1.Have high break down voltage
2.Low junction capacitance
3.Large delpetion region
4.The intrinsic region provides a greater separation between the PN and N regions, allowing higher reverse voltages to be tolerated thus used as high voltage switches
5. PIN diodes are much faster and more sensitive than p–n junction diodes

Disadvantages of PIN photodiode:
1.The response time of the PIN diode is somewhat slower than of the p-n diode.
2. Photodiode should be always operated in reverse bias condition.</td><td>Advantages 1M

Disadvantages 1M</td></tr>
<tr><td></td><td>(b)
Ans.</td><td>Compare between photodiode and PIN diode.
<table>
<tr><th>Photodiode</th><th>PIN Diode</th></tr>
<tr><td>Photodiode consists of a normal p-n junction housed in a small enclosure which a transparent window through which light can fall inside</td><td>A PIN diode (p-type, intrinsic, n-type) is a diode with a wide, undoped intrinsic semiconductor region between p-type semiconductor and n-type semiconductor regions.</td></tr>
<tr><td>The working principle of a photodiode is, when a photon of ample energy strikes the diode, it makes a couple of an electron-hole. This mechanism is also called as the inner photoelectric effect</td><td>Typically P-I-N diode operates at any wavelength shorter than cutoff wavelength. When light falls, energy of absorbed photon must be sufficient enough to promote electron across the bandgap. Otherwise it will not get absorbed. Material will absorb photons of any energy which is higher than the bandgap energy. P-I-N diodes operate at different wavelengths with different materials used in the construction.</td></tr>
</table></td><td>4M

Any 4 points 1M each</td></tr>
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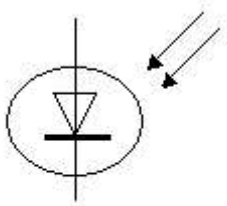
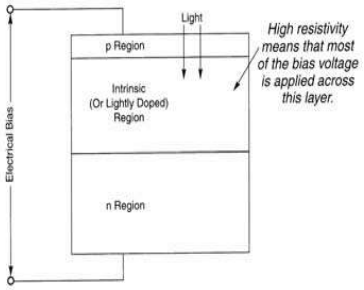
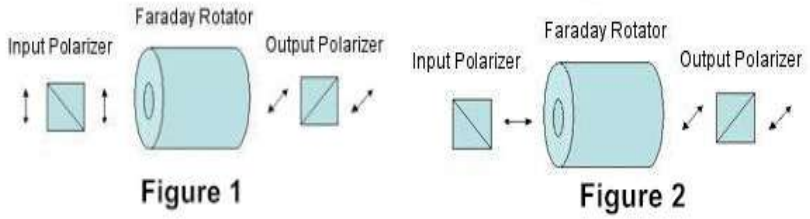
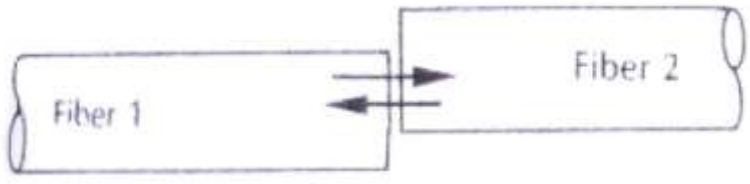
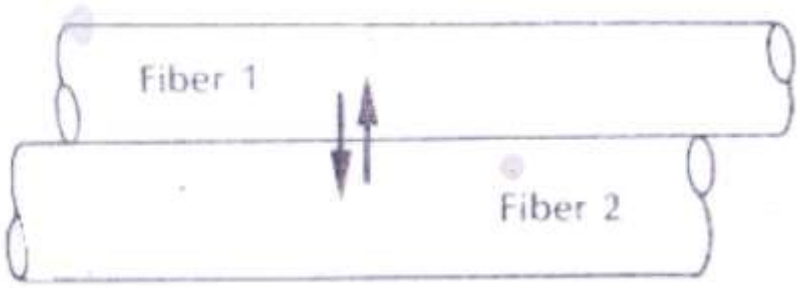
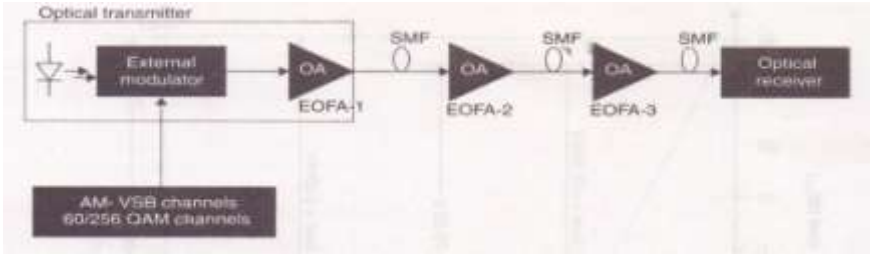
			
		Photodiodes are used as fast counters and used in light meters to measure the light energy	The intrinsic region provides a greater separation between the PN and N regions, allowing higher reverse voltages to be tolerated thus used as high voltage switches
	(c) Ans.	**Draw and explain the operation of optical isolator. State it's use.** An optical isolator, is an optical component which allows the transmission of light in only one direction. It is typically used to prevent unwanted feedback into an optical oscillator, such as a laser cavity. The operation of the device depends on the Faraday effect (which in turn is produced by magneto-optic effect), which is used in the main component, the Faraday rotator. **Working Principle of Optical Isolator:** An optical isolator contains three components, an input polarizer, a Faraday rotator and an output polarizer. As showed in Figure 1, light traveling in the forward direction passes through the input polarizer and becomes polarized in the vertical plane. Upon passing through the Faraday rotator, the plane of polarization will have been rotated 45° on axis. The output polarizer, which has been aligned 45° relative to the input polarizer will allow the light to pass unimpeded. As Figure 2 illustrates, light traveling in the reverse direction will pass through the output polarizer and become polarized at 45°. The light will then pass through the Faraday rotator and experience an additional 45° of nonreciprocal rotation. The light is now polarized in the horizontal plane and will be rejected by the input polarizer which only allows light polarized in the vertical plane to pass unimpeded.	**4M** ***Explanation 2M***

		 **Uses:** Optical isolator is used in many optical applications in corporate, industrial, and laboratory settings. They are reliable devices when used in conjunction with fiber optic amplifiers, fiber optic ring lasers, fiber optic links in CATV applications, and high-speed and coherent fiber optic communication systems. Single polarization fiber optic isolators are also used with laser diodes, gyroscopic systems, optical modular interfaces, and a variety of other mechanical control and testing applications.	***Diagram 1M*** ***Use 1M***
	(d) Ans.	**State the functions of core interaction type and surface interaction type fibre couplers.** **Functions of core interaction type and surface interaction type fiber couplers:** Couplers are devices that distribute optical signals from the main fiber to one or many branches of the fiber. Optical fiber couplers are passive devices in which power can be transferred from one fiber to anathor by either buttjoining the core cross section or by surface interaction. The two categories of these fibers couplers are as shown figure.  **Diagram: Core Interaction type**	**4M** ***Functions 2M*** ***Diagram 1M each***

		 **Diagram: surface interaction type**	
	(e) Ans.	**Draw the hybrid multichannel analog and digital optical system. State it's application.**  **Diagram of hybrid multichannel analog and digital optical system** **Applications:** The deployment of hybrid multichannel analog and digital optical system is industry drive. That is, economic incentives dictated an investigation into the possibility of jointly transmitting analog and digital video signals over optical links at relatively low cost.	**4M** ***Diagram 2M*** ***Application 2M***