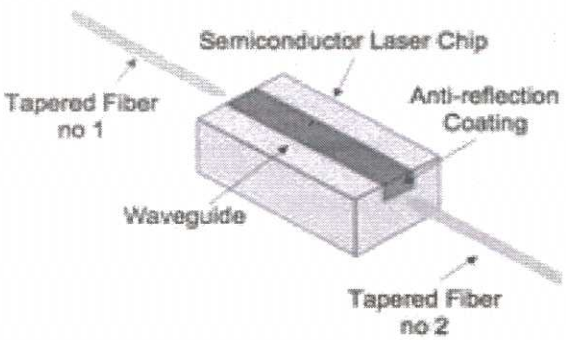
159

Page: 17
April: 2024

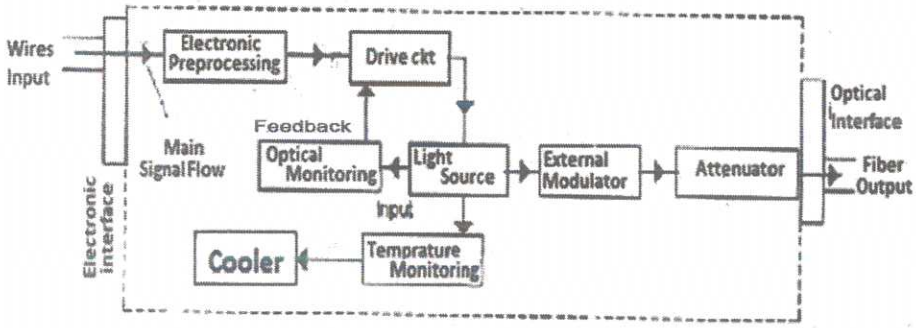
SCORING INDICATORS

	Course Code: 5043A **Revision :2021** **Course Title : : Optical Communication and Networking** **QID : 2109230095**	**SET 2**		
Qn. No.	**Scoring Indicator**	**Split score**	**Sub Total**	**Total Score**
	PART A			9
I.1	Refractive index is the speed of light in a vacuum (abbreviated c, c=299,792.458km/second) divided by the speed of light in a material (abbreviated v).	1	1	1
I.2	Single mode fiber Multimode fiber	1	1	1
I.3	Population inversion is the process of achieving greater population of higher energy state as compared to the lower energy state.	1	1	1
I.4	Light Emitting Diode	1	1	1
I.5	• Coherence • Directionality • Monochromatic • High intensity	1	1	1
I.6	Signal attenuation in an optical fiber is defined as the decrease in light power during light propagation along an optical fiber	1	1	1
I.7	An optical amplifier amplifies light as it is without converting the optical signal to an electrical signal,	1	1	1
I.8	SONET stands for Synchronous Optical Network.	1	1	1
I.9	A beam splitter is an optical device which can split an incident light beam into two (or sometimes more) beams, which may or may not have the same optical power.	1	1	1
	PART B			24
II 1	n1 sin ϕi = n2 sin ϕr Given angle of incidence ϕi = **30^0** n1 =ref. Index of air=1 Refractive index of glass= n2 =1.52 Applying the equation Sin ϕr = 0. 318 Angle of refraction = $\sin^{-1}$ 0.318 = 18.54^0	3	3	3

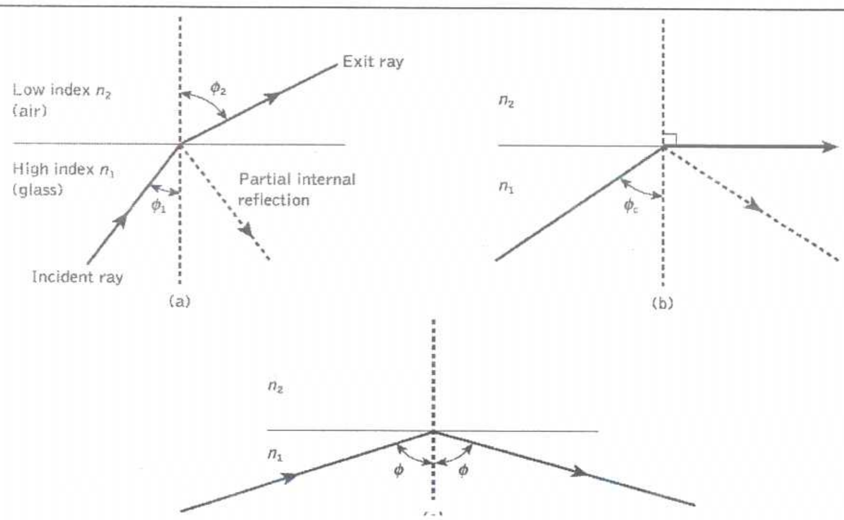
<table>
<tr><td>II 2</td><td>
<table>
<tr><th>Characteristic</th><th>PIN photodiode</th><th>APD photodiode</th></tr>
<tr><td>Sensitivity</td><td>Lower</td><td>Higher</td></tr>
<tr><td>Noise</td><td>Lower</td><td>Higher</td></tr>
<tr><td>High intensity electric field.</td><td>No.</td><td>Yes</td></tr>
<tr><td>Generated photocurrent</td><td>Less</td><td>More</td></tr>
<tr><td>Response time</td><td>Faster</td><td>Slower</td></tr>
</table>
</td><td>3x1=3</td><td>3</td><td>3</td></tr>
<tr><td>II 3</td><td>Bend losses in optical fiber are the losses that occur in optical fibers due to its bending. It occur when the fiber optic cable is bent too tightly or too sharply, causing some of the light to escape from the fiber core. This results in a loss of signal strength and a decrease in overall performance.

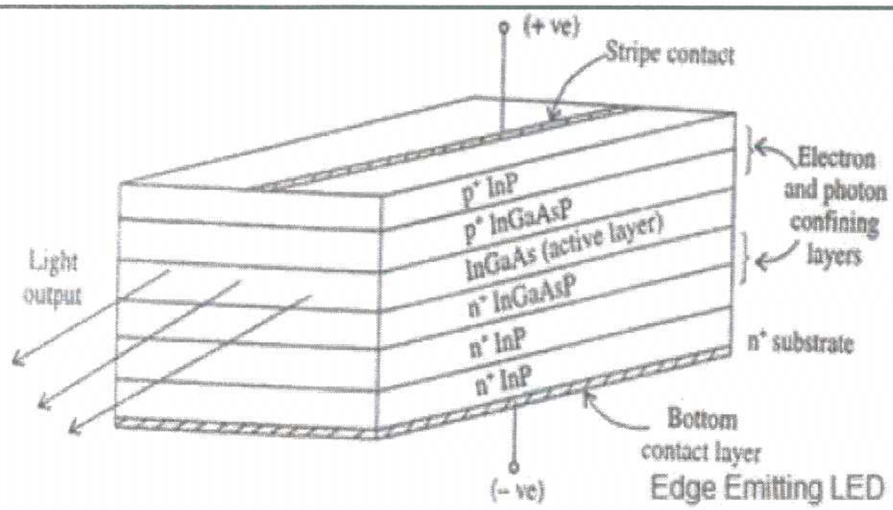
There are two main types of bend losses in optical fiber:
Macrobending losses: These losses occur when the fiber is bent over a large radius, such as around a corner or a tight bend. Macro-bending losses are caused by the fact that when a fiber is bent, the light inside the fiber travels a longer distance through the core. This longer distance gives the light more chances to interact with the cladding and other imperfections in the fiber, which can cause it to be absorbed or scattered.
Microbending losses: These losses occur when the fiber is bent over a very small radius, such as when it is wrapped around a cable tie or when it is crushed. Microbending losses are caused by the fact that the small bends in the fiber cause the light to travel through different parts of the core with different refractive indices. This difference in refractive indices causes the light to be scattered, which can lead to signal loss.</td><td>2x1.5 =3</td><td>3</td><td>3</td></tr>
<tr><td>II 4</td><td>

The SOA is pumped with an electrical current. This creates a population inversion in the semiconductor, where more electrons are in the conduction band than in the valence band. An optical signal enters the SOA. This stimulates the emission of photons from the conduction band to the valence band. The emitted photons have the same wavelength as the input signal, which amplifies the signal. The amplified signal exits the SOA.</td><td>Fig-1.5 Expln-1.5</td><td>3</td><td>3</td></tr>
<tr><td>II 5</td><td>Scattering loss in optical fiber is the loss of light due to its interaction with</td><td>3</td><td>3</td><td>3</td></tr>
</table>

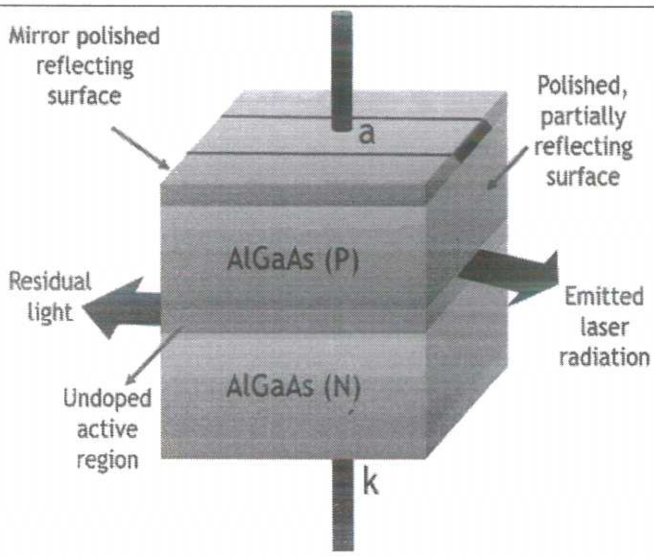
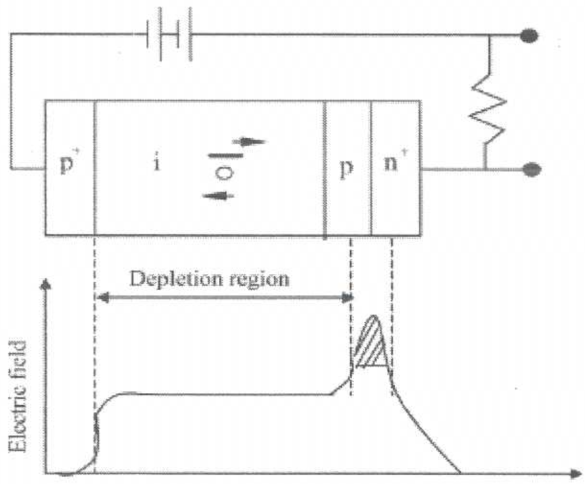
	imperfections in the fiber core and cladding. These imperfections can be caused by the manufacturing process, environmental factors, or mechanical stress. There are two main types of scattering loss in optical fiber: Rayleigh scattering: This type of scattering is caused by the interaction of light with the random density fluctuations of the fiber material. Rayleigh scattering is inversely proportional to the fourth power of the wavelength of light, meaning that shorter wavelengths are scattered more than longer wavelengths. Mie scattering: This type of scattering is caused by the interaction of light with larger imperfections in the fiber core and cladding, such as bubbles, dust particles, and microbends. Mie scattering is not as wavelength-dependent as Rayleigh scattering, but it can be a significant source of loss at all wavelengths.			
II 6	 Optical transmitter	Fig-3	3	3
II 7	An optical modulator is a device that is used to control the properties of light, such as its intensity, phase, or polarization. Optical modulators are used in a wide variety of applications, including optical fiber communications, displays, and laser technology. The function of an optical modulator depends on the type of modulator. Some common types of optical modulators include -Mach-Zehnder interferometer (MZI), Electro-optic modulator (EOM), Acousto-optic modulator (AOM).	3	3	3
II 8	The function of an optical isolator is to allow light to propagate in only one direction. This is useful in a variety of applications, such as preventing unwanted feedback into an optical oscillator, such as a laser cavity. Optical isolators are also used in high-power applications, where one desires one-way transmission of light. Optical isolators typically work by using the Faraday effect, which is a magneto-optic phenomenon in which the plane of polarization of light is rotated as it passes through a material in the presence of a magnetic field. The Faraday effect is reversible, but the direction of the rotation depends on the direction of the magnetic field.	3	3	3
II 9	Broadcast and select networks are simple and inexpensive to implement, but they have a number of limitations. In a broadcast and select network, all wavelengths are broadcast to all nodes on the network. Each node then selects the wavelength that it needs and ignores the other wavelengths. Wavelength routed networks are more complex and expensive to implement than broadcast and select networks, but they offer a number of	1.5+ 1.5 =3	3	3

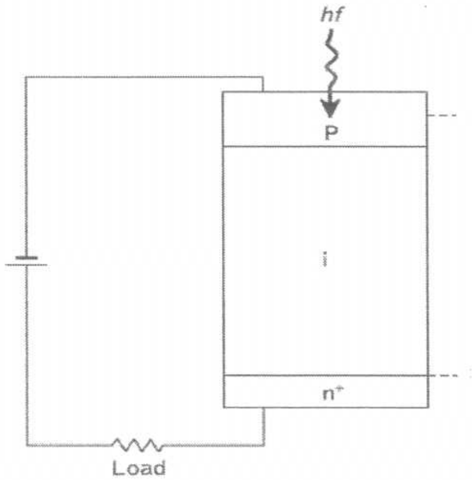
	advantages. In a wavelength routed network, each wavelength is assigned to a specific path between two nodes. This allows for more efficient bandwidth utilization and reduces crosstalk between the different wavelengths.			
II 10	An optical fiber connector terminates the end of an optical fiber, and enables quicker connection and disconnection than splicing. The connectors mechanically couple and align the cores of fibers so light can pass. Better connectors lose very little light due to reflection or misalignment of the fibers. In all, about 100 different types of fiber optic connectors have been introduced to the market. Rather than using optical fiber connectors, it is possible to splice two optical fibers together. An fiber optic splice is defined by the fact that it gives a permanent or relatively permanent connection between two fiber optic cables, That said, some manufacturers do offer fiber optic splices that can be disconnected, but nevertheless they are not intended for repeated connection and disconnection. There are many occasions when fiber optic splices are needed. One of the most common occurs when a fiber optic cable that is available is not sufficiently long for the required run, in this case it is possible to splice together two cables to make a permanent connection.. Fiber optic splices can be undertaken in two ways: 1. Mechanical splices 2. Fusion splices	2x1.5 =3	3	3
	PART C			42
III	*(a) Enormous potential bandwidth* :The optical carrier frequency in the range 10^{13} to 10^{16} Hz (generally in the near infrared around 10^{14} Hz or 10^{5} GHz) yields a far greater potential transmission bandwidth than metallic cable systems *(b) Small size and weight.* Optical fibers have very small diameters which are often no greater than the diameter of a human hair *(c) Electrical isolation.* Optical fibers which are fabricated from glass, or sometimes a plastic polymer, are electrical insulators *(d) Immunity to interference and crosstalk.* Optical fibers form a dielectric waveguide and are therefore free from electromagnetic interference (EMI), *(e) Signal security.* The light from optical fibers does not radiate significantly and therefore they provide a high degree of signal security *(f) Low transmission loss.* The development of optical fibers over the last 20 years has resulted in the production of optical fiber cables which exhibit very low attenuation or transmission loss in comparison with the best copper conductors *(g) Ruggedness and flexibility.* Optical fibers may be manufactured with very high tensile strengths. *(h) System reliability and ease of maintenance.* The low-loss property of optical fiber cables reduces the requirement for intermediate repeaters or line amplifiers to boost the transmitted signal strength *(i) Potential low cost.* The glass which generally provides the optical fiber transmission medium is made from sand – not a scarce resource.	7x1=7	7	7

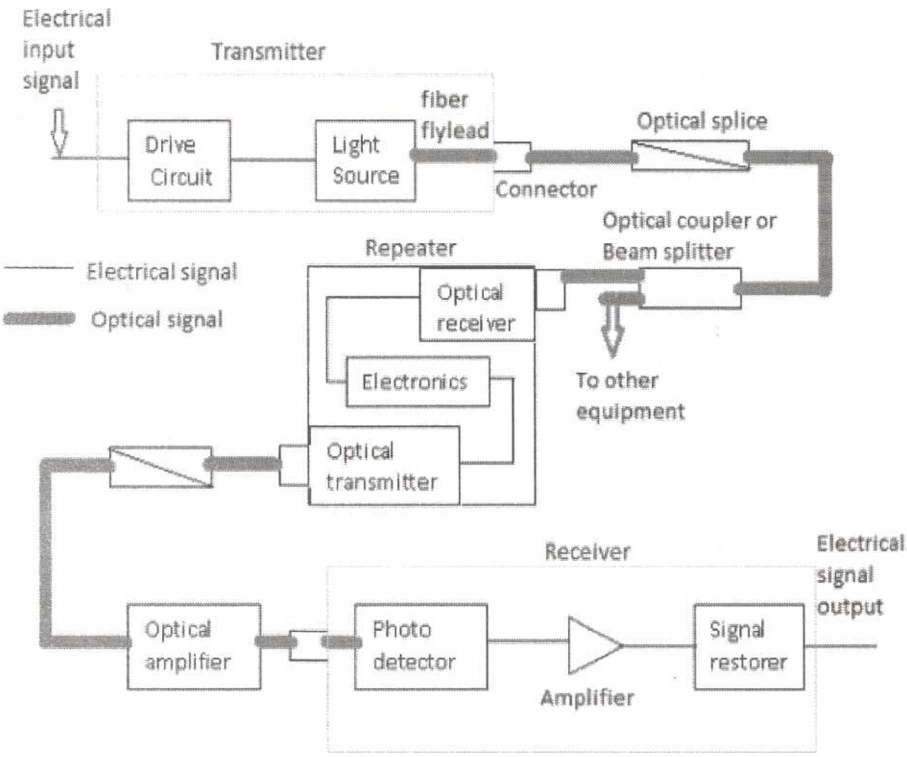
IV	Critical angle $\phi_c = \sin^{-1}(n_2/n_1)$ $= \sin^{-1}(1.45/1.5)$ $= 75.01^0$ Numerical aperture NA $= \sqrt{(n_1^2 - n_2^2)}$ $= \sqrt{(1.5^2 - 1.45^2)}$ $= 0.38$ Acceptance angle $= \sin^{-1}$ NA $= \sin^{-1} 0.38$ $= 22.33^0$	2+3+2 =7	7	7
V	Numerical aperture NA $= \sqrt{(n_1^2 - n_2^2)}$ $0.26 = \sqrt{(1.5^2 - n_2^2)}$ Refractive index of cladding $= n_2 = 1.477$ Acceptance angle $= \sin^{-1}$ NA $= \sin^{-1} 0.26$ $= 15.07^0$	4+3=7	7	7
VI	 (c) Total internal reflection Total internal reflection (TIR) is a phenomenon that occurs when a ray of light travelling from a denser medium to a less dense medium is incident at an angle greater than the critical angle. In this case, the ray of light is completely reflected back into the denser medium, and no refraction occurs. The critical angle is the angle of incidence at which the refracted ray is parallel to the boundary between the two media. For light traveling from water to air, the critical angle is approximately 48.5 degrees.TIR has many applications in optics, including: Optical fibers: TIR is used to transmit light signals through optical fibers, which are thin strands of glass or plastic. The light rays are trapped inside the fiber by TIR, and can be transmitted over long distances with very little loss.	Fig-3 Expln- 4	7	7

<table>
<tr>
<td>VII</td>
<td>


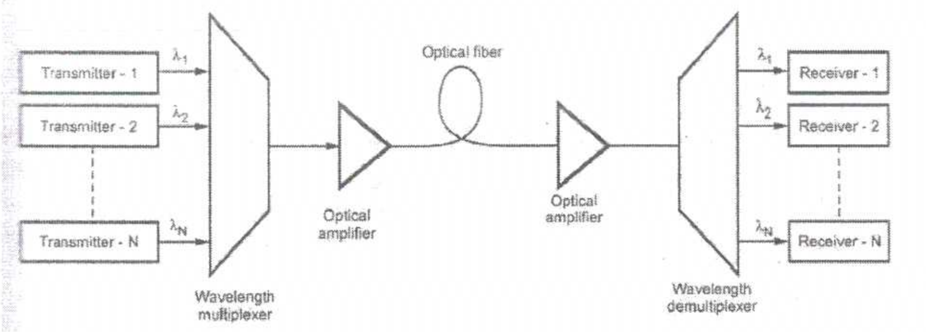
Edge Emitting LED
In order to reduce the losses caused by absorption in the active layer and to make the beam more directional, light is collected from the edge of the LED. Such a device is known as edge emitting LED or ELED. It consists of an active junction region which is the source of incoherent light and two guiding layers. The refractive index of guiding layers is lower than active region but higher than outer surrounding material. Thus a waveguide channel is form and optical radiation is directed into the fiber. Fig. shows structure of ELED
•It is widely used in optical fiber communication system. Here collimated light from LED is required to be fed into the fiber with high coupling efficiency.
•The figure depicts multilayer structure of InP based edge emitting LED. It is used for long wavelength optical communication approx. between 1.33 to 1.55 μm.
•Modern epitaxial growth techniques such as MBE, MOCVD etc. are used in order to design such complex LED structures.
•Central active layer is made using InGaAs having narrow bandgap. It is bounded by wide bandgap layers such as p+ InGaAsP and n+ InP cladding layers.
•These two cladding layers help in confining injected electrons and holes into the middle layer. It also helps emitted photons to travel along LED axis as per optical properties.
•Due to above, light is emitted from the edge of the LED. Hence it is known by the name edge emitting LED.
Edge emitter's emission pattern is more concentrated (directional) roviding improved coupling efficiency.
</td>
<td>Fig-4
Expln-
3</td>
<td>7</td>
<td>7</td>
</tr>
</table>

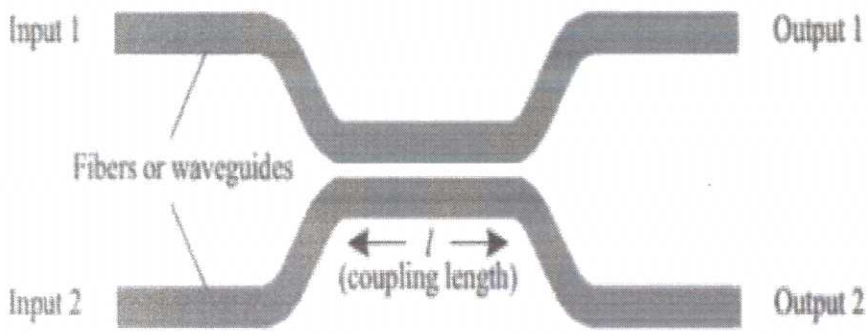
VIII	 The input terminals are connected to a metal plates which are sandwiched to the n-type and p-type layers. This type of laser diode is also called as a "Homojunction Laser Diode". The intrinsic region between the p-type and n-type material is used to increase the volume of active region, so that more number of holes and electrons can accumulate at the junction. This allows more number of electrons to recombine with holes at any instant of time, resulting in better output power. The laser light is emitted from the elliptical region. This beam from the laser diode can be further focused using an optical lens. This entire PIN diode (P-type, Intrinsic, N-Type) arrangement is enclosed normally in a metal casing.	Fig-4 Expln- 3	7	7
IX	 ➢ APD is similar to PIN diode the exception is the addition of high intensity electric field region. ➢ In this region primary electron hole pairs are generated by the incident photons which are able to absorb enough kinetic energy from strong electric field to collide with the atoms present in this region, thus generating more electron hole pairs. ➢ This process of generating more than one electron hole pair from	Fig-3 Expln- 4	7	7

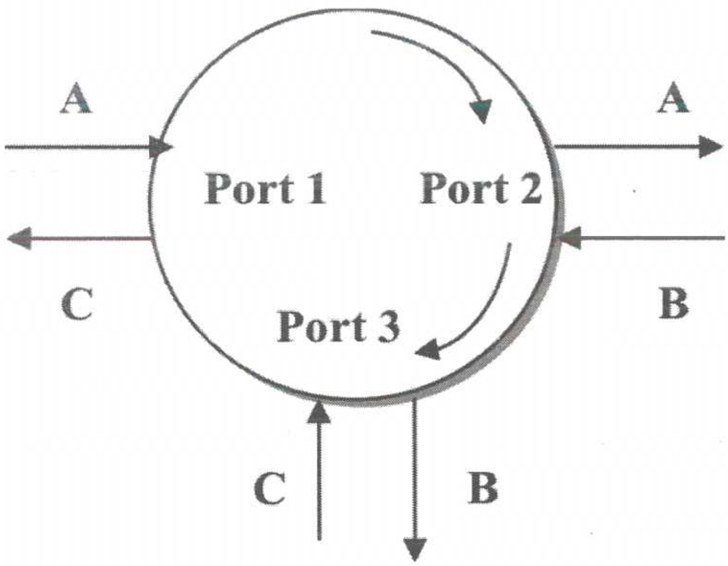
<table>
<tr><td></td><td>incident photon through ionization process is referred to as the avalanche effect.
➢ Thus the avalanche multiplication results in mplification of photodiode current.</td><td></td><td></td><td></td></tr>
<tr><td>X</td><td>

Incident photon having energy greater than or equal to the band gap energy of the semiconductor material excite an electron from the valence band to the conduction band.The high electric field present in the depletion region causes photogenerated carriers to separate and be collected across the reverse – biased junction. This gives rise to a current flow in an external circuit, known as photocurrent.</td><td>Fig-3
Expln-4</td><td>7</td><td>7</td></tr>
<tr><td>XI</td><td>

Message origin:</td><td>Fig-3
Expln-4</td><td>7</td><td>7</td></tr>
</table>

	Generally message origin is from a transducer that converts a non-electrical message into an electrical signal. **Modulator:** The modulator has two main functions. 1) It converts the electrical message into proper format. 2) It impresses this signal onto the wave generated by the carrier source. **Carrier source:** Carrier source generates the wave on which the information is transmitted. For fiber optic system, a laser diode (LD) or a light emitting diode (LED) is used.. **Channel coupler:** Coupler feeds the power into information channel. For an atmospheric optic system, the channel coupler is a lens used for collimating the light emitted by the source and directing fiber system because of possibility of high losses. **Information channel:** The information channel is the path between the transmitter and receiver. **Optical detector:** The information begin transmitted is detected by detector. In the fiber system the optic wave is converted into an electric current by a photodetector.. **Signal processing:** Signal processing includes filtering, amplification. Proper filtering maximizes the ratio of signal to unwanted power **Message output:** The electrical form of the message emerging from the signal processor is transformed into a sound wave or visual image.			
XII	 Optical signals of different wavelength (1300-1600 nm) can propagate without interfering with each other. The scheme of combining a number of wavelengths over a single fiber is called wavelength division multiplexing (WDM). Each input is generated by a separate optical source with a unique wavelength. An optical multiplexer couples light from individual sources to the transmitting fiber. At the receiving station, an optical demultiplexer is required to separate the different carriers before photo detection of individual signals. Fig. 7.1.1 shows WDM scheme. To prevent spurious signals to enter into receiving channel, the demultiplexer	Fig-3 Expln-4	7	7

<table>
<tr><td></td><td>must have narrow spectral operation with sharp wavelength cut-offs. The acceptable limit of crosstalk is – 30 dB. Features of WDM are Capacity upgrade , Transparency, Wavelength switching etc. .</td><td></td><td></td><td></td></tr>
<tr><td>XIII</td><td>

A directional coupler is used to combine and split signals in an optical network. A 2x2 coupler consists of two input port and two output ports. The most commonly used couplers are made fusing two fibers together in the middle. These are called fused fibre coupler. A 2x2 coupler takes a fraction of power from input port 1 and places it on output port 1 and the remaining fraction on output port 2. Similarly a fraction of power from input port 2 is distributed to output port 2 and the remaining power to output port1.</td><td>Fig-3
Expln-4</td><td>7</td><td>7</td></tr>
<tr><td>XIV</td><td>

An optical circulator is a non-reciprocal optical device that directs light entering one port to the next port in a fixed sequence. It is a three- or four-port device, and the direction of light propagation is not affected by the polarization of the light. Optical circulators are used in a variety of applications, including optical communication systems, fiber optic sensors, and laser systems. Light entering port 1 exits from port 2, light entering port 2 exits from port 3, and light entering port 3 exits from port 1. This sequence is fixed and cannot be reversed. Optical circulators are typically</td><td>Fig-3
Expln-4</td><td>7</td><td>7</td></tr>
</table>

	made using a combination of polarizing beam splitters and Faraday rotators. A Faraday rotator is a device that rotates the polarization of light by a fixed amount, depending on the direction of propagation. The polarization beam splitters split the light beam into two beams based on their polarization. Optical circulators are used in a variety of applications, including: Bidirectional transmission over a single fiber optic cable Isolating lasers from back reflections Protecting optical detectors from damage			

QID 2109230095
SUBJECT : REV (21) 5043A
SET 2
BLUE PRINT

Module	Hr/Module - hi	(hi / ΣHi) * 123	TYPE OF QUESTIONS							
			PART A		PART B		PART C		TOTAL	
			No. of Questions	Marks	No. of Questions	Marks	No. of Questions	Marks	No. of Questions	Marks
I	14	**30**	2	2	1	3	4	28	7	33
II	16	**34**	3	3	1	3	4	28	8	34
III	14	**30**	2	2	4	12	2	14	8	28
IV	14	**30**	2	2	4	12	2	14	8	28
Total	**58**	**123**	**9**	**9**	**10**	**30**	**12**	**84**	**31**	**123**
			9		10		12			

Cognitive Level Wise Question Analysis

Mark Distribution

Cognitive Level	% marks	Marks	TYPE OF QUESTIONS							
			PART A		PART B		PART C		**TOTAL**	
			No. (Questi		‹o. of ıestions	Marks	No. of Questions	Marks	**No. of Questions**	**Marks**
R	17.1	21	9	9	4	12	0	0	**13**	**21**
U	80.5	99	0	0	5	15	12	84	**17**	**99**
A	2.4	3	0	0	1	3	0	0	**1**	**3**
Total	**100**	**123.0**	**9**	**9**	**10**	**30**	**12**	**84**	**31**	**123**
			9		10		12		31	