CBCS SCHEME

USN | | | | | | | | | |

15EC82

Eighth Semester B.E. Degree Examination, July/August 2021
Fiber Optics and Networks

Time: 3 hrs. Max. Marks: 80

Note: ***Answer any FIVE full questions.***

1 a. Explain with a neat diagram an optical fiber communication system. **(06 Marks)**
b. Derive an equation for numerical aperture for a step index fiber using Snell's law. **(07 Marks)**
c. A silica optical fiber with a core diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and cladding refractive index of 1.47. Determine:
i) Critical angle at the core – cladding interface
ii) The numerical aperture for the fiber
iii) The acceptance angle in air for the fiber. **(03 Marks)**

2 a. Discuss the advantages of optical fiber communication. **(05 Marks)**
b. Explain photonic crystal fibers. **(07 Marks)**
c. A graded index fiber has core with a parabolic refractive index profile which has a diameter of 50μm. The fiber has a numerical aperture of 0.2 estimate the total number of guided modes propagating in the fiber when it is operating at a wave length of 1μm. **(04 Marks)**

3 a. Explain intrinsic and extrinsic absorption losses. **(06 Marks)**
b. Explain fiber bending losses with the help of neat diagrams. **(06 Marks)**
c. When the mean optical power launched into an 8km length of fiber is 120μw, the mean optical power at the fiber output is 3μw. Determine :
i) The overall signal attenuation or loss in the decibels through the fiber assuming there are no connectors or splices.
ii) The signal attenuation per kilometer for the fiber
iii) The overall signal attenuation for a 10km optical link using the same fiber with splices at 1km intervals, each giving an attenuation of 1dB
iv) The numerical input/output power ration in (iii). **(04 Marks)**

4 a. Derive an expression for r.m.s pulse broadening due to intermodal dispersion in a step index fiber. **(06 Marks)**
b. Explain three types fiber splicing techniques with neat diagrams. **(06 Marks)**
c. An optical fiber has a core refractive index of 1.5. Two lengths of the fiber with smooth and perpendicular (to the core axis) end faces are butted together. Assuming the fiber axis are perfectly aligned, calculate the optical loss in decibels at the joint (due to Fresnel reflection) when there is a small air gap between the fiber end faces. **(04 Marks)**

5 a. With neat sketch, explain GaAs homo-injection LASER Fabry – Perot cavity. **(06 Marks)**
b. Derive an expression for quantum efficiency and LED power. **(06 Marks)**
c. Discuss the operation of PIN photodetector with appropriate diagrams. **(04 Marks)**

6 a. With a neat schematic diagram, explain the working of an optical receiver. **(06 Marks)**
b. Explain the different types of front end amplifiers in an optical receiver. **(06 Marks)**
c. A double – heterojunction In GaAsP LED emitting at a peak wavelength of 1310nm has radiative and nonradiative recombination times of 30 and 100ns, respectively. The drive current is 40mA. Calculate : i) bwk recombination lifetime ii) internal quantum efficiency iii) internal power. **(04 Marks)**

7 a. With the help of neat diagram, explain the operation of WDM (Wavelength Division Multiplexing). **(08 Marks)**
b. Derive an equation for path difference in a 2 × 2 Mach – Zehnder interferometer. **(08 Marks)**

8 a. Explain the operation of polarization independent isolator. **(06 Marks)**
b. Explain the three possible configurations of an EDFA (Erbium doped Fiber amplifiers). **(10 Marks)**

9 a. Briefly discuss the evolution of optical networks indicate the significant features of the optical network generations. **(06 Marks)**
b. Describe the concept of OXC (Optical Cross Connect) and a ROADM (Reconfigurable optical add/drop multiplexer) outline how they are utilized in the development of large scale wavelength division multiplexed networks. **(06 Marks)**
c. Define what is ATM(Asynchronous Transmission Mode) and its application in optical networks. **(04 Marks)**

10 a. Describe the purpose and the layered structure of Open System Interconnection (OSI) reference model. **(08 Marks)**
b. Outline the main features of the optical transport network and describe its hierarchy as specified by ITU-T. **(08 Marks)**

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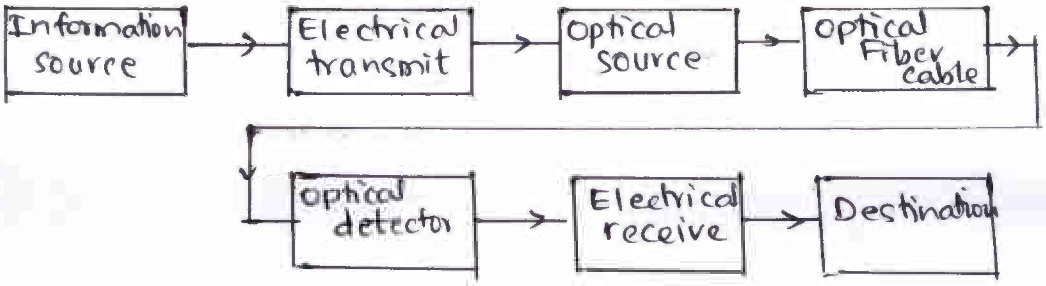
Scheme & Solution

Signature of Scrutinizer

Subject Title : FIBER OPTICS and NETWORKS **Subject Code :** 15EC82

Question Number	Solution	Marks Allocated
	MODULE : 1	

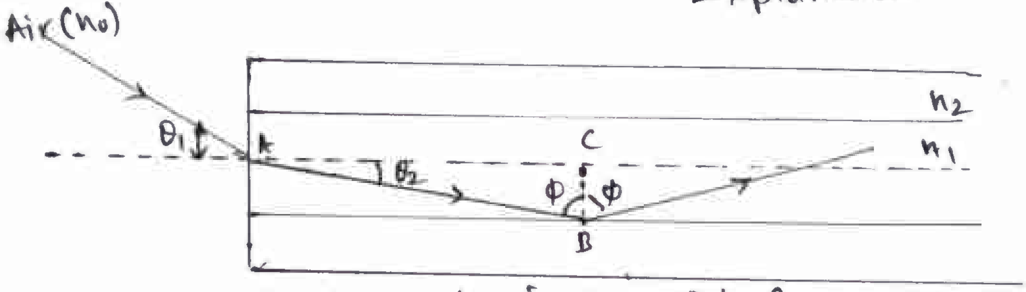
1 (a)



2M

Explanation — 4M

(b)



2M

Applying Snell's law at air core interface

$n_0 \sin\theta_1 = n_1 \sin\theta_2$

Consider ΔABC $\phi = \frac{\pi}{2} - \theta_2$

ϕ is greater than critical angle at the core cladding interface

$n_0 \sin\theta_1 = n_1 \cos\phi = n_1 (1 - \sin^2\phi)^{1/2}$ — 2M

Considering Limiting case for total internal reflection

ϕ becomes critical angle and $\theta_1 \rightarrow$ acceptance angle

$n_0 \sin\theta_a = (n_1^2 - n_2^2)^{1/2}$ — 3M

$NA = n_0 \sin\theta_a = (n_1^2 - n_2^2)^{1/2}$

NA interms of R.I. difference Δ ; $NA = n_1 (2\Delta)^{1/2}$

(c)

(i) $\phi_c = \sin^{-1}\frac{n_2}{n_1} = 78.5^\circ$ — 1M

(ii) $NA = (n_1^2 - n_2^2)^{1/2}$

$= (1.50^2 - 1.47^2)^{1/2}$ — 1M

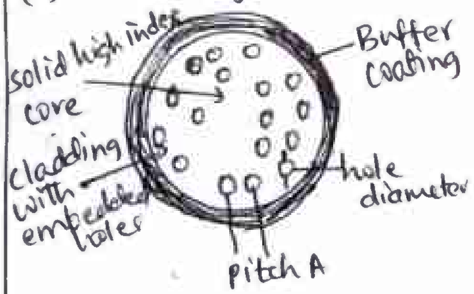
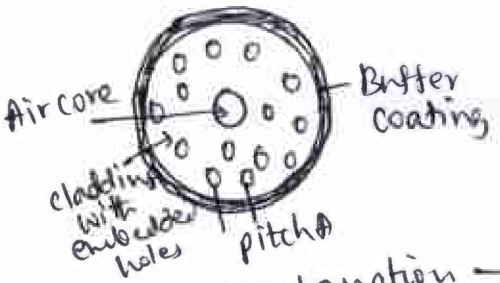
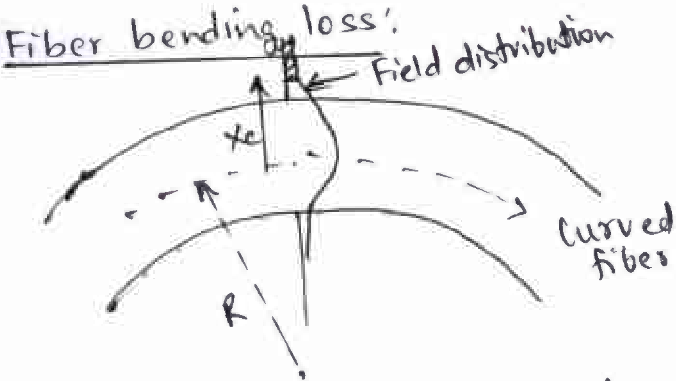
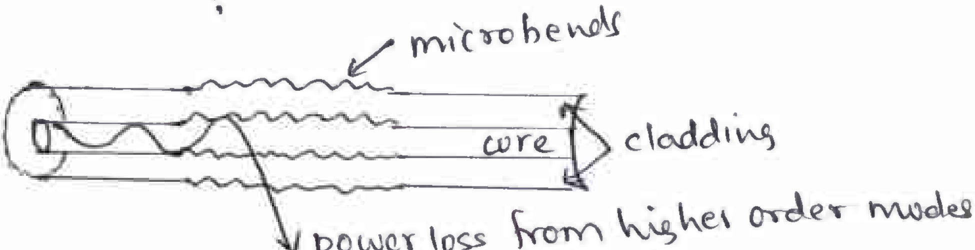
$= 0.30$

(iii) $\theta_a = \sin^{-1} NA$

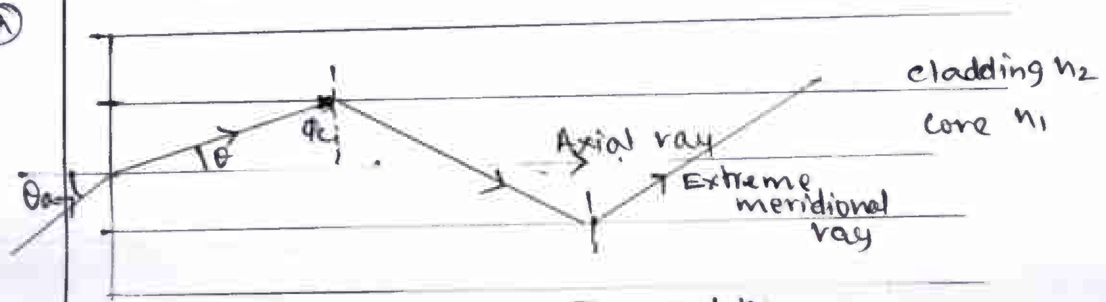
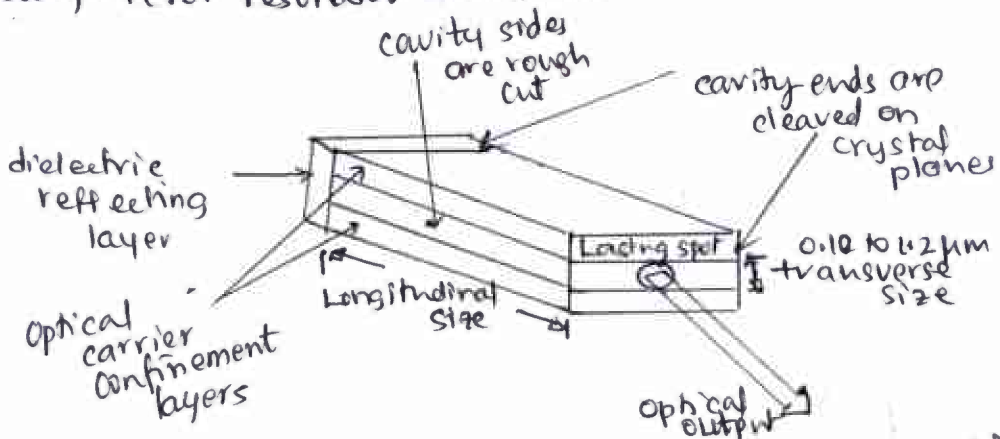
$= \sin^{-1} 0.30$ — 1M

$= 17.4^\circ$

Subject Title : FIBER OPTICS and NETWORKS **Subject Code :** 15EC82

Question Number	Solution	Marks Allocated
2 (a)	Advantages of OFC: (i) Enormous potential BW (ii) Small size and weight (iii) Electrical isolation (iv) Immunity to interference & crosstalk (v) Signal security (vi) Low transmission loss (vii) Ruggedness and Flexibility (viii) System reliability and ease of maintenance (ix) Potential low cost. + Explanation	2M 3M
(b)	Photonic crystal fibers: (i) Index guiding PCF (ii) Photonic bandgap fiber. Explanation —	3M 4M.
(c)	(i) $V = \frac{2\pi}{\lambda} a(NA) = \frac{2\pi \times 25 \times 10^{-6} \times 0.2}{1 \times 10^{-6}} = 31.4$ (ii) $m_g \approx \frac{V^2}{4} = \frac{986}{4} = 247$	2M 2M.
3 (a)	MODULE: 2 Intrinsic absorption: is due to its basic material structure in the near infrared region. + Explanation Extrinsic absorption: optical fibers prepared by conventional melting techniques. Extrinsic absorption is from transition metal elements. + Explanation	1M 2M. 1M 2M.
(b)	Fiber bending loss: diagrams + Explanation 	2M. 4M.

Subject Title : FIBER OPTICS and NETWORKS **Subject Code :** 15EC82

Question Number	Solution	Marks Allocated
3 (c)	(i) Signal attenuation: $10\log\frac{P_i}{P_o} = 16\,dB$	1M
	(ii) signal attenuation per km $\alpha_{dB} = \frac{16}{8} = 2\,dB/km$	1M
	(iii) overall signal attenuation : $\alpha_{dB}\times L + 9dB = 29\,dB$	1M
	(iv) $\frac{P_i}{P_o} = 10^{29/10} = 794.3$	1M
4 (a)	 	2M
	$T_{min} = Ln_1/c$ $\quad T_{max} = \frac{Ln_1}{c\cos\theta}$ $\sin\phi_c = n_2/n_1 = \cos\theta$, $\therefore T_{max} = Ln_1^2/cn_2$	2M
	delay difference $\delta T_s = T_{max} - T_{min} = \frac{Ln_1^2\Delta}{cn_2}$ $\delta T_s = \frac{L(NA)^2}{2n_1c}$ r.m.s. pulse broadening: $\sigma_s = \frac{Ln_1\Delta}{2\sqrt{3}\,c}$	2M
4 (b)	Fiber splices: A permanent joint between two individual optical fibers in the field or factory is known as fiber splice.	2M
	Fusion splices, Mechanical splices, Multiple splices + diagram + Explanation	4 M
(c)	$r = \left[\frac{n_1 - n}{n_1 + n}\right]^2 = 0.04$	2M
	$Loss_{Fres} = -10\log(1-r) = -10\log 0.96 = 0.18\,dB$	2M.
	MODULE : 3	
5 (a)	Fabry - Perot resonator cavity for Laser diode.  	2M
	Explanation	4M.

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Question Number	Solution	Marks Allocated

5 (b) Rate equation for carrier concentration in an LED

$$\frac{dn}{dt} = J/qd - n/\tau$$

Equillibrium condition $n = J\tau/qd$ — 2M

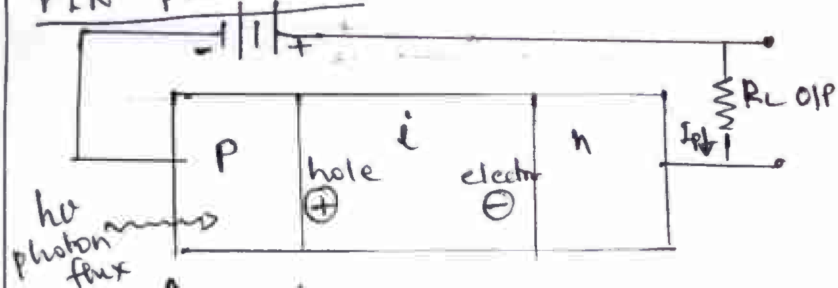
Internal quantum efficiency $\eta_{int} = \frac{R_r}{R_r + R_{nr}}$.

$P_{int} = \eta_{int} \frac{I}{q} h\nu = \eta_{int} \frac{hcI}{q\lambda}$ — 2M

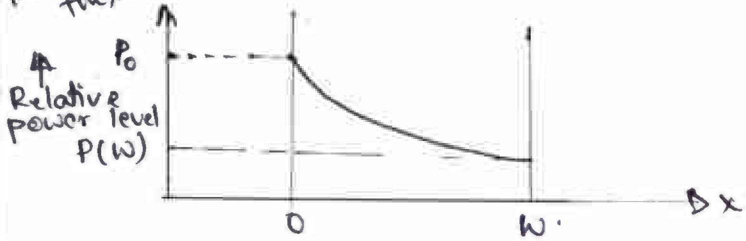
$\eta_{ext} \approx \frac{1}{n(n+1)^2}$

Power emitted from $P = \eta_{ext} P_{int} = \frac{P_{int}}{n(n+1)^2}$. — 2M

5 (c) PIN photodiode:

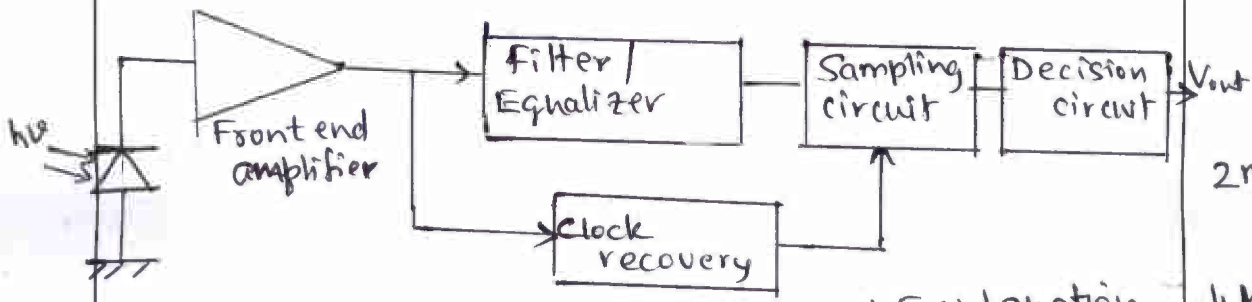


— 2M



\+ Explanation — 2M.

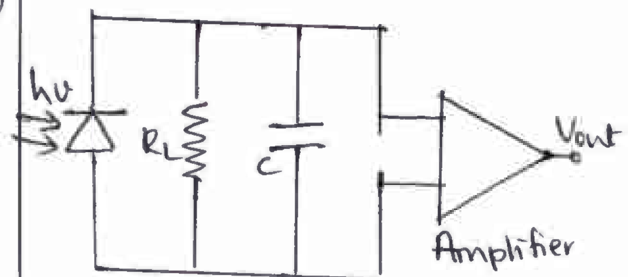
6 (a)



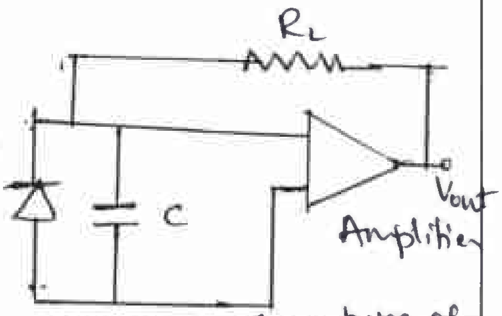
— 2M

\+ Explanation — 4M.

(b)



generic structure of high impedance amplifier



generic structure of transimpedance amplifier. — 3M

Explanation — 3M.

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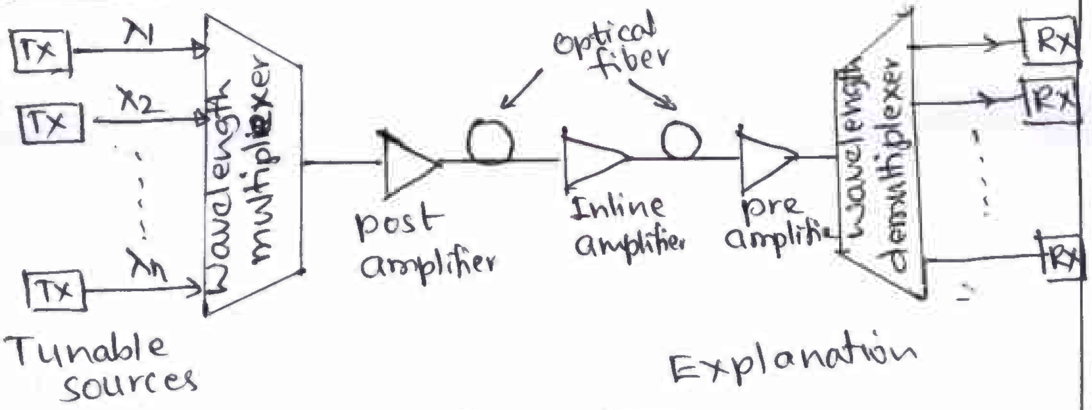
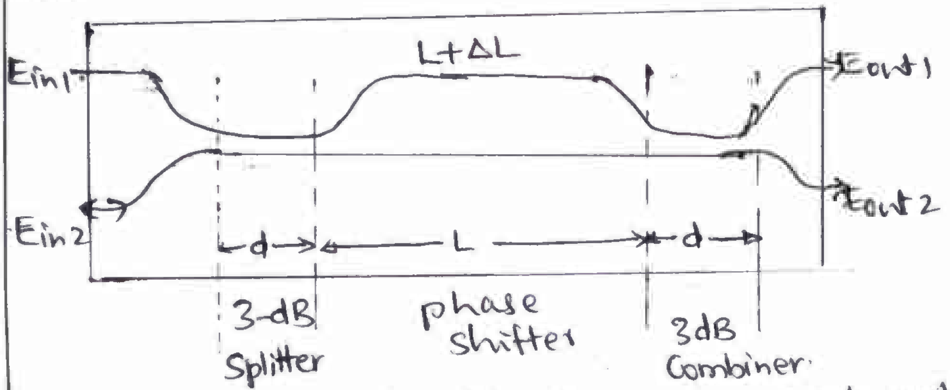
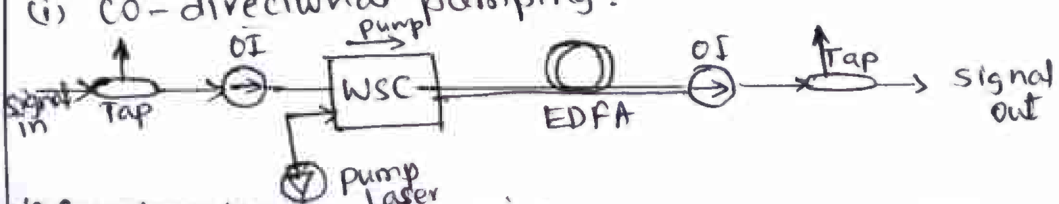
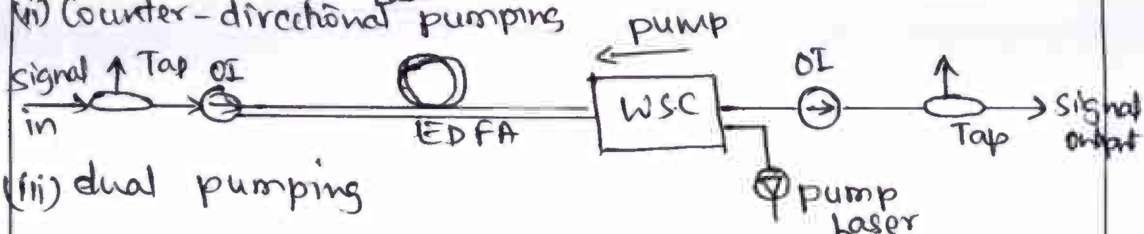
Question Number	Solution	Marks Allocated
6 (c)	$\tau = \frac{\tau_r \tau_{nr}}{\tau_r + \tau_{nr}} = \frac{30 \times 100}{30+100} = 23.1\,ns$	
	Internal quantum efficiency $\eta_{int} = \frac{\tau}{\tau_r} = \frac{23.1}{30} = 0.77$	2M
	$P_{int} = \eta_{int} \frac{hcI}{q\lambda} = 29.2\,mW$	2M.
	MODULE : 4	
7 (a)	WDM:	
		3M
	Explanation	5M.
(b)	Mach-Zehnder Interferometer:	
		2M
	Consists of 3dB directional coupler which splits the input signals. In central section one of the waveguide is longer by ΔL. A 3dB coupler which recombines the signals.	
	propagation matrix $M_{coupler} = \begin{bmatrix} \cos kd & j\sin kd \\ j\sin kd & \cos kd \end{bmatrix} = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & j \\ j & 1 \end{bmatrix}$	
	$\Delta\phi = \frac{2\pi n_1}{\lambda} L - \frac{2\pi n_2}{\lambda}(L+\Delta L)$	
	$M_{\Delta\phi} = \begin{bmatrix} \exp(jk\Delta L/2) & 0 \\ 0 & \exp(-jk\Delta L/2) \end{bmatrix}$	2M

Subject Title : FIBER OPTICS and NETWORKS   Subject Code : 15EC82

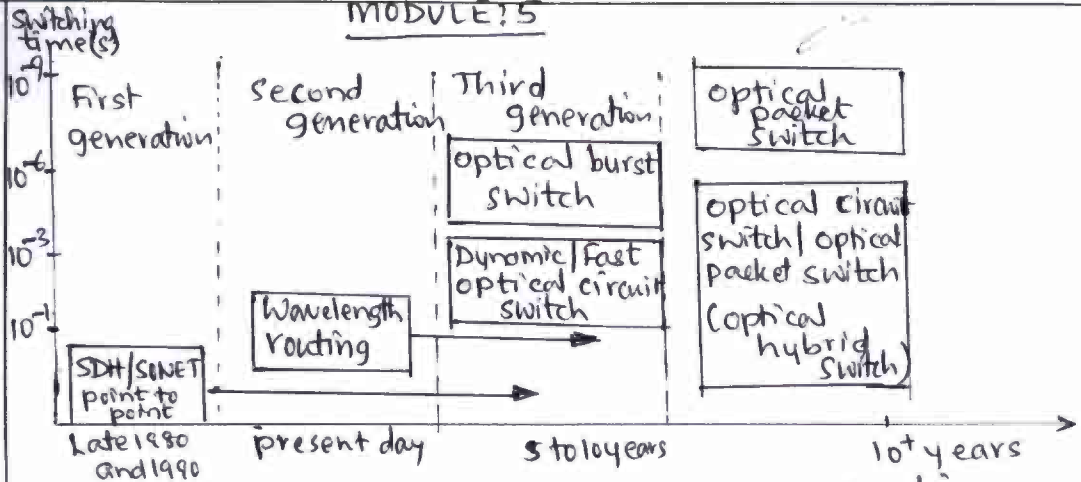
Question Number	Solution	Marks Allocated
	$\begin{bmatrix} E_{out1} \\ E_{out2} \end{bmatrix} = M \begin{bmatrix} E_{in1} \\ E_{in2} \end{bmatrix}$	
	$M = M_{coupler} M_{\Delta\phi} M_{coupler} = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} = j \begin{bmatrix} \sin k\Delta L/2 & \cos k\Delta L/2 \\ \cos k\Delta L/2 & -\sin k\Delta L/2 \end{bmatrix}$	
	$E_{out1} = j[E_{in1} \lambda_1 \sin(k_1 \Delta L/2) + E_{in2}(\lambda_2) \cos k_2 \Delta L/2]$	
	$E_{out2} = j[E_{in1} \lambda_1 \cos(k_1 \Delta L/2) - E_{in2} \lambda_2 \sin k_2 \Delta L/2]$	2m
	$P_{out1} = E_{out1} E^*_{out1} = \sin^2(k_1 \Delta L/2) P_{in1} + \cos^2(k_2 \Delta L/2) P_{in2}$	
	$P_{out2} = E_{out2} E^*_{out2} = \cos^2(k_1 \Delta L/2) P_{in1} + \sin^2(k_2 \Delta L/2) P_{in2}$	
	Length difference in interferometer $\Delta L = \left[2 n_{eff} \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)\right]^{-1} = \frac{c}{2 n_{eff} \Delta\nu}$	2m.
	$\Delta\nu$ – freq separation of the two wavelengths	
8 (a)	Optical isolators are devices that allow light to pass through them in only one direction.	
	Common application of isolator is to keep backward travelling light from entering LASER diode.	2m.
	diagram + Explanation	4m.
(b)	(i) CO-directional pumping: 	
	(ii) Counter-directional pumping 	
	(iii) dual pumping 	6M
	Explanation —	4M

Subject Title : FIBER OPTICS and NETWORKS Subject Code : 15EC82

Question Number	Solution	Marks Allocated

MODULE:5

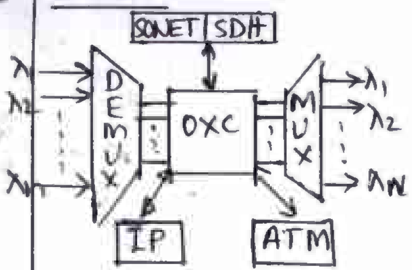
9 (a)



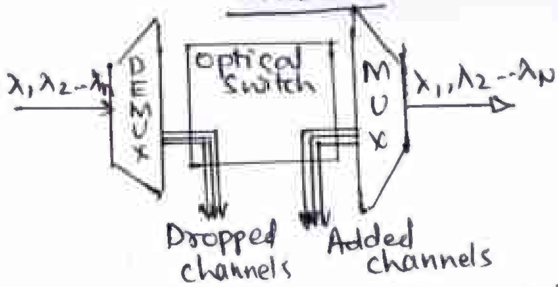
3M

Explanation 3M

(b) OXC :



ROADEM:



2M

Explanation 4M

9 (c) Asynchronous transmission mode:

ATM is a packetised multiplexing and switching technique which combines the benifits of packet switching and circuit switching

2M

Header (5 bytes)	Payload (48 bytes)

Format of an ATM cell

Explanation — 2M

Description of OSI reference model:

10 (a)

	Layers	Function	Data unit	
7	Application	Network process to application	Data	Host layers
6	presentation	Data representation & encryption		
5	session	Interhost communication		
4	Transport	End to end connections and reliability	segments	
3	Network	Path determination and logical addressing	packets	Media layers
2	Data link	Physical addressing	Frames	
1	Physical	Media, signal and binary transmission	Bits	

4M

Explanation 4 M.

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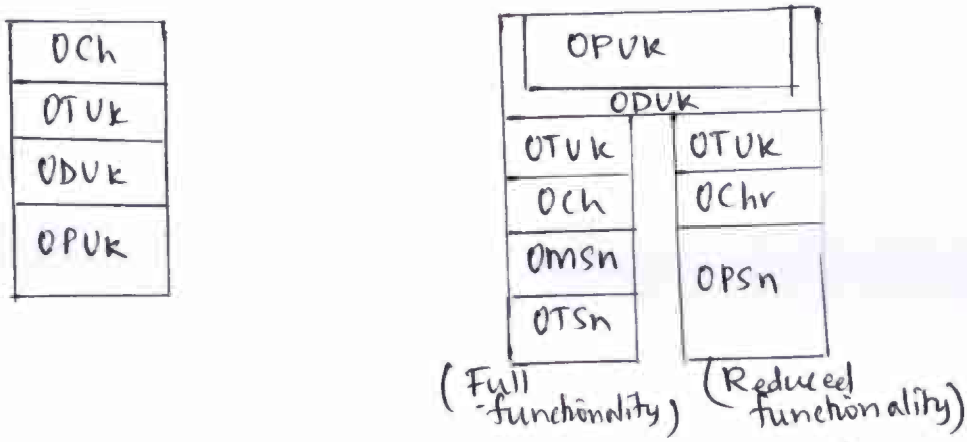
Question Number	Solution	Marks Allocated
10 (b)	optical transport network is regarded as the set of fascilities using optical fiber interconnections to carry data between network elements that switch or route the data from different customers into the network.	2M
	A typical hierarchy: Hierarchy specified by ITU-T 	3M
	Explanation	3M.