Modified

CBCS SCHEME

USN | | | | | | | | | | |

17EC82

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

Time: 3 hrs. Max. Marks:100

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



1 a. Outline any light advantages of optical fibers over copper wires or coaxial cables that are used in communication links as transmission media. **(08 Marks)**

b. Define Numerical Aperture(NA) and what is its significance. With an optical ray diagram and by derivation relate NA and core-cladding refractive indices as well as NA and relative refractive index Δ. **(08 Marks)**

c. With a simple block diagram, briefly explain the digital optical communication link that employs optical fiber. **(04 Marks)**

2 a. With neat sketches of the refractive index profile and light ray transmissions, explain the features of : i) multimode step index fiber ii) single mode step index fiber iii) multimode graded index fiber (parabolic RI profile). **(11 Marks)**

b. A multimode step index fiber with core diameter of 80μm and a relative index difference of 1.5% is operating at a wave length of 0.85μm. If core RI is 1.48, find :
i) the normalized frequency (or V number for the fiber) ii) the number of modes guided by the fiber. **(04 Marks)**

c. Compare the meridional optical rays and skew optical rays in an optical fiber. **(05 Marks)**

3 a. The mean optical power launched into a fiber of length 8kms is 120 μW and the mean optical power at the fiber output end is 3 μW. Find :
i) The overall signal attenuation in dB without any connectors or splices.
ii) The signal attenuation per kilometer for the fiber
iii) The overall signal attenuation for a 10 km optical link using the same type of fiber with splices at 1 km intervals, each giving an attenuation of 1dB. **(06 Marks)**

b. Explain the phenomena of : i) material absorption and ii) linear scattering in optical fibers that lead to losses of optical signals. **(10 Marks)**

c. With a neat diagram, explain the technique of fusion splice for optical fibers. **(04 Marks)**

4 a. Outline any six principal feature requirements of a good optical fiber connector. **(06 Marks)**

b. With a neat diagram of illustrative schematic, briefly explain the basic principle of operation and three advantages of expanded beam connectors. **(07 Marks)**

c. A 32 × 32 port multimode fiber transmissive star coupler has 1mW of optical power launched into a single input port. The average optical power at each output port is 14μW. Find the total loss incurred by the star coupler and the average insertion loss through the coupler. **(07 Marks)**

5 a. With a neat schematic explain the structure and features of a high radiance surface emitting LED. **(08 Marks)**

b. Explain briefly the three key photon transition processes involved in laser action. **(03 Marks)**

c. Show the derivation of the mathematical expression that estimates the amount of photon emissions per unit volume, starting from the two rate equations of laser diode. **(09 Marks)**

6 a. With relevant diagrams, explain the principles of conversion of optical signal into electrical signal by a PIN photodatector. **(08 Marks)**

b. What are the three principal noises associated with photodetectors? Briefly explain how they originate. **(06 Marks)**

c. Explain the operation of a digital optical receiver with a block diagram showing basic sections. **(06 Marks)**

7 a. With a neat block diagram, explain the operational principles and implementation of a WDM optical network. **(06 Marks)**

b. Explain the construction and working of an optical isolator. **(06 Marks)**

c. Based on the general applications, explain the three types of optical amplifiers with relevant block diagrams. **(08 Marks)**

8 a. Explain the construction and working of a dielectric thin film optical filter. **(06 Marks)**

b. With relevant diagrams, explain the construction and operation of reflection and transmission type diffraction gratings. **(08 Marks)**

c. With neat diagram, explain the operation of a MEMS technology based actuation mechanism. **(06 Marks)**

9 a. With a neat diagram, explain the optical public telecommunication network hierarchy. **(07 Marks)**

b. With neat diagram, explain the optical circuit switched network. **(06 Marks)**

c. Briefly explain each of the seven layers of OSI reference model. **(07 Marks)**

10 a. What are the four basic functions performed by an optical packet switch? Show the overall structural format of a typical packet used in the optical packet switched network and briefly explain. **(07 Marks)**

b. Show the structure of a metropolitan area network and explain. **(06 Marks)**

c. With a neat block diagram, briefly explain the generic Optical Label Switched (OLS) network configuration. **(07 Marks)**

* * * * *

## Re: Sir, regarding Modification of scheme and solution (17EC82)

"Mrityunjaya Vithal Latte" <mvlatte@rediffmail.com>

July 31, 2021 11:39 AM

To: boe@vtu.ac.in

Dear sir,

The scheme of 17EC82 is verified and it is inline with the question paper .
Regards

PROF. MRITYUNJAYA V. LATTE
Principal,
JSS Academy of Technical Education,
Uttarahalli-Kengeri Main Road,Bangalore
Karnataka 560 060

From: <boe@vtu.ac.in>
Sent: Fri, 30 Jul 2021 10:48:15
To: mvlatte@rediffmail.com, mvlatte25@gmail.com
Subject: Sir, regarding Modification of scheme and solution (17EC82)

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B-E
Registrar (Evaluation)
Visvesvaraya Technological University
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# Visvesvaraya Technological University

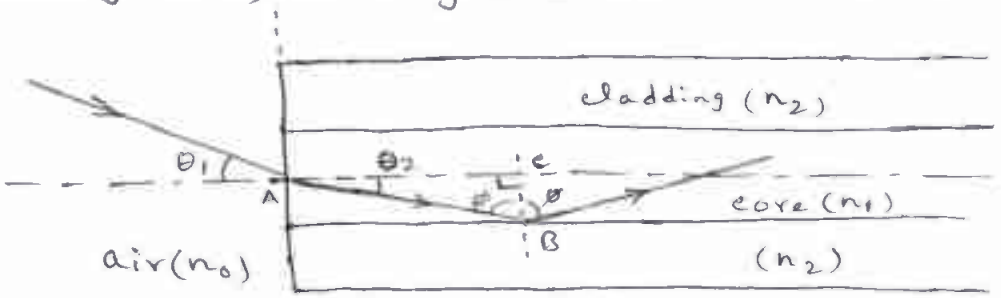
Belagavi, Karnataka - 590 018



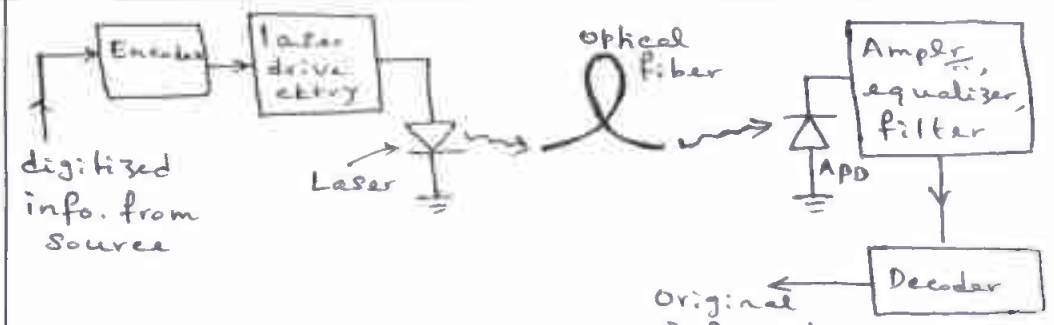
**Scheme & Solutions**

Signature of Scrutinizer

**Subject Title :** Fiber Optics & Networks **Subject Code :** 17EC82

| Question Number | Solution | Marks Allocated |
|---|---|---|
| 1 a) | 1) Enormous potential band width 2) Small size & light weight 3) Electrical isolation 4) Immunity to noise interference & cross talk 5) Signal security 6) low transmission loss 7) Ruggedness & flexibility 8) system reliability and ease of maintanance 9) potential low cost — mention any eight with brief explanation for each | 1 mark X 8 |
| 1 b) | NA defines the light gathering capability of an optical fiber | 1 mark |
| | NA gives the relationship b/n acceptance angle & refractive indices of three media involved namely core, cladding and air | 1 mark |
| |   ↑ ray diagram | 2 marks |
| | air-core interface | |
| | Acc. to Snell's law $n_0 \sin\theta_1 = n_1 \sin\theta_2$ | 1 mark |
| | From rt angled $\Delta$le $\phi = \frac{\pi}{2} - \theta_2$ | |
| | $\therefore n_0 \sin\theta_1 = n_1 \cos\phi$ | |
| | $\Rightarrow n_0 \sin\theta_1 = n_1\sqrt{1-\sin^2\phi}$ | 1 mark |
| | With limiting case for TIR, $\phi = \phi_c \Rightarrow \theta_1 = \theta_a$ | |
| | $\therefore n_0 \sin\theta_a = n_1\sqrt{1-\sin^2\phi_c}$ | |
| | $= n_1\sqrt{1-(n_2/n_1)^2}$ | 1 mark |
| | $\therefore$ NA $\doteq n_0 \sin\theta_a = \sqrt{n_1^2 - n_2^2}$ ($\Rightarrow$ NA in terms of RI of core & cladding) | |
| | $NA = \sqrt{(n_1+n_2)(n_1-n_2)}$ | |
| | With $n_1 \cong n_2$, $NA = \sqrt{2n_1(n_1-n_2)}$ | |
| | $n_1 - n_2 \cong n_1\Delta$ $\therefore NA = n_1\sqrt{2\Delta}$ ($\Rightarrow$ NA in terms of rel. RI $\Delta$) | 1 mark |

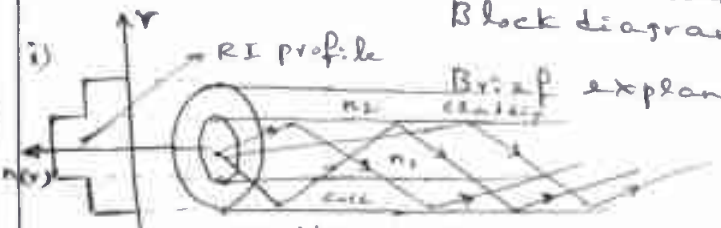
**1 c)**




Block diagram → 2 marks

**2 a)**

i) RI profile

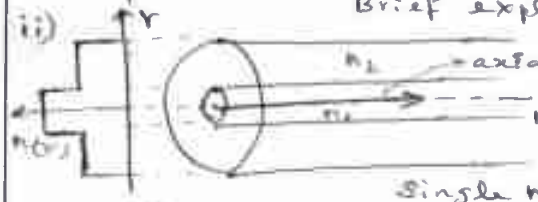



Brief explanation → 2 marks

multimode SIF — diagram → 2 marks

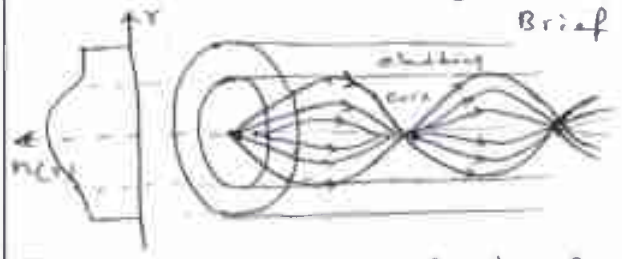
Brief explanation of features → 2 marks

ii)




Single mode SIF — diagram → 1 mark

Brief explanation of features → 2 marks




Multimode GIF — diagram → 2 marks

Brief explanation of features → 2 marks

**2 b)** $V = \frac{2\pi}{\lambda} a n_1 \sqrt{2\Delta}$  $a = d/2 = \frac{80\mu m}{2} = 40\mu m$, $n_1 = 1.48$

$\Delta = 0.015$  $\lambda = 0.85\mu m$

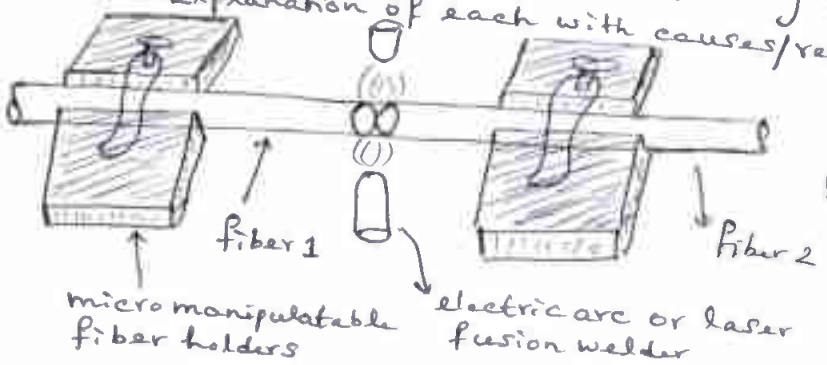
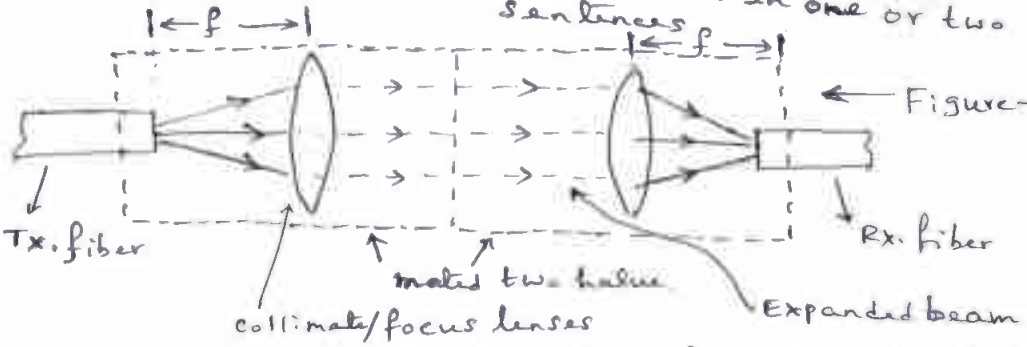
$V = \underline{75.8}$ → 2 marks

**2 c)** Total no. of guided modes $M_s = \frac{V^2}{2} = \frac{(75.8)^2}{2} = \underline{2873}$ → 2 marks.

| Meridional rays | Skew rays |
|---|---|
| 1) Follow zig-zag paths | • helical paths |
| 2) They cross fiber axis | • Do not cross, propagate in the annular region near outer surface of core |
| 3) non uniform o/p from fiber | • uniform o/p from fiber |
| 4) core is fully utilized by these rays | • Do not fully utilize the core |
| 5) lower light gathering capacity is offered to a fiber | • larger light gathering capa-city is offered |
| 6) acceptance angle of meridional rays are smaller than that of skew rays i.e $\theta_a < \theta_{as}$ | • acc. angle of skew rays are larger than that of meridional ray |

Any five comparisons → 1 mark X 5

Subject Title : Fiber Optics & Networks  Subject Code : 17EC82

| Question Number | Solution Page 3 of 9 | Marks Allocated |
|---|---|---|
| 3 a) | i) Overall signal attenuation $\alpha_{dB}L = 10\log_{10}\left(\frac{P_i}{P_o}\right)$ <br> $P_i = 120\times10^{-6}$ W, $P_o = 3\times10^{-6}$ W <br> $= 10\log_{10}\frac{120\times10^{-6}}{3\times10^{-6}}$ <br> $= 10\log_{10}(40) = 16$ dB <br> ii) $\alpha_{dB}L = 16$ dB <br> $L = 8$ km $\therefore$ Attenuation per km is $\alpha_{dB} = \frac{16\text{ dB}}{L} = \frac{16}{8} = 2$ dB/km <br> iii) Overall signal attenuation by the 10km fiber alone is $\alpha_{dB}L = 2\text{ dB/km} \times 10\text{km} = 20$ dB <br> Since 10km link uses splices at 1 km interval, totally 9 splices are needed. <br> Since each splice causes 1 dB attenuation, total attenuation by splices alone is $1\text{dB}\times 9 = 9$ dB <br> Hence overall attenuation in 10 km fiber link $= 20\text{dB} + 9\text{dB} = 29$ dB | → 2 marks <br> → 1 mark <br> → 1 mark <br> → 1 mark <br> → 1 mark |
| 3 b) | Material absorption → intrinsic absorption, Extrinsic absorption <br> Explanation of each with cause/reasons & effects <br> Linear scattering → Rayleigh scattering, Mie scattering <br> Explanation of each with causes/reasons/effects | → 1 mark <br> → 2 marks X 2 <br> → 1 mark <br> → 2 marks X 2 |
| 3 c) |   <br> Diagram → 2 marks <br> Explanation of fusion splicing process | → 2 marks |
| 4 a) | i) low coupling losses ii) Interchangeablity iii) Ease of assembly iv) Low environmental sensitivity v) Low cost & reliable construction vi) Ease of connection in the field — Explanation in one or two sentences | → 1 mark X 6 |
| 4 b) |   <br> Figure → 2 marks <br> Explanation of basic working principle | → 2 marks |

**Advantages:**

- Less requirements of lateral alignment of fibers
- Less necessity of "minimum longitudinal separation b/n the two mated halves of the connector system
- Optical processing/controlling components can be easily inserted into the expanded beam region b/n the fiber ends

→ 1 mark X 3

**4c)** No. of o/p ports $N = 32$

Splitting loss $= 10\log_{10}(N) = 10\log_{10}(32) = 15.05$ dB → 1 mark

Excess loss (formula) $= 10\log_{10}\left[\frac{P_i}{\sum_1^N P_j}\right]$, $P_i = 1\text{ mW} = 1000\,\mu\text{W}$ → 1 mark

$\sum_1^N P_j \Rightarrow \sum_1^{32}$ (Avg. o/p power at each port) → 1 mark

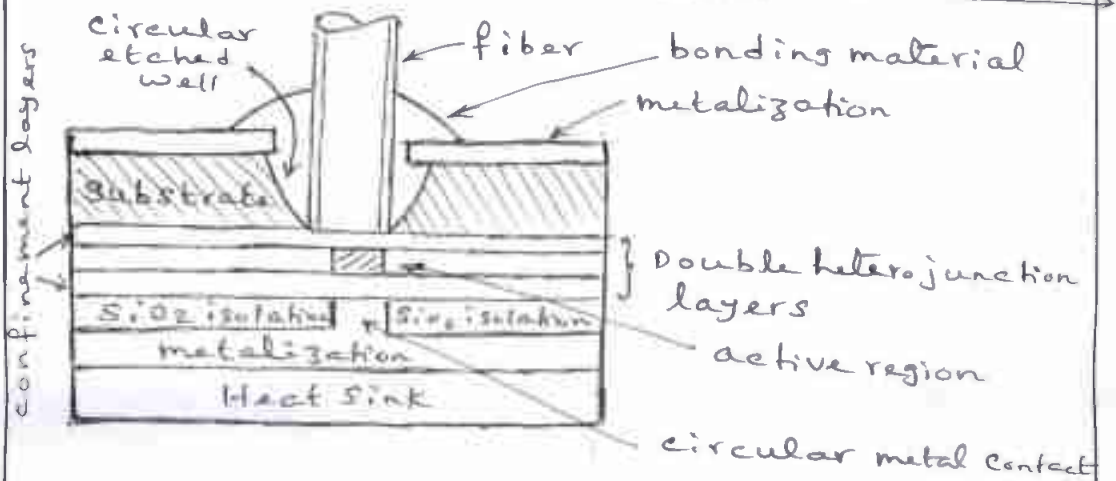
$P_j = 14\,\mu\text{W}$ (given) $\therefore \sum_1^N P_j \Rightarrow \sum_1^{32}(14\,\mu\text{W}) = 32 \times 14 = 448\,\mu\text{W}$ → 1 mark

Excess loss $= 10\log_{10}\left[\frac{1000\,\mu\text{W}}{448\,\mu\text{W}}\right] = 3.49$ dB → 1 mark

Total loss = splitting loss + excess loss $= (15.05 + 3.49)$ dB $= 18.54$ dB → 1 mark

Insertion loss $= \frac{1000\,\mu\text{W}}{14\,\mu\text{W}} = 18.54$ dB → 1 mark

**5a)**



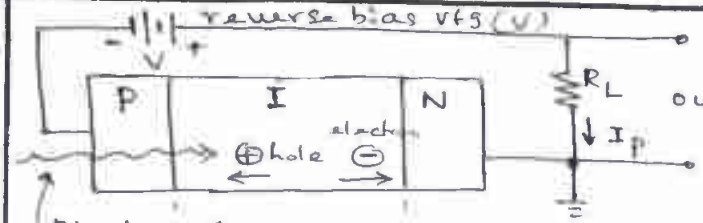

Schematic diagram → 4 marks

**Structure:** Through the substrate a well is etched to which fiber is cemented. The plane of the active emitting region is perpendicular to the axis of the fiber. Two different alloy layers on each side of the active region is the heterostructure. Both carriers and optical field are confined to the central active layer → 2 marks

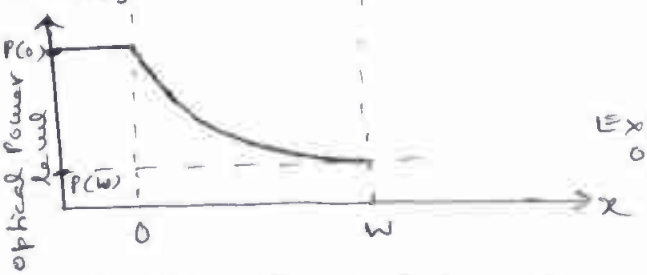
| Question Number | Solution | Marks Allocated |
|---|---|---|
| | features : High radiance and high quantum efficiency is achieved due to carrier and field confinement to the active layer by the heterostructure. The emission pattern is isotropic with 120° half power beamwidth which is also known as Lambertian pattern. In this pattern the LED source is equally bright when viewed from any direction. But the power diminishes as $\cos\theta$ where $\theta$ is the angle b/n the viewing direction and the normal to the surface | → 2 marks. |
| 5 b) | i) Photon absorption ii) spontaneous emission iii) stimulated emission — explanation of each in one or two sentences or illustrate with diagram | → 1 mark x 3 |
| 5 c) | Laser diode rate eqns. $\frac{d\phi}{dt} = Cn\phi + R_{sp} - \frac{\phi}{\tau_{ph}}$ ← eqn ① ; $\frac{dn}{dt} = \frac{J}{qd} - \frac{n}{\tau_{sp}} - Cn\phi$ ← eqn ② | → 2 marks |
| | In eqn ①, first of all assuming that the rate of spontaneous photon emission $R_{sp}$ is negligible. For small no. of photons $\phi$, $\frac{d\phi}{dt}$ must be +ve. Thus eqn ① is written as $Cn - \frac{1}{\tau_{ph}} \geq 0$ ← eqn ③ | → 2 marks |
| | Eqn ③ implies that, no. of electrons n must exceed a threshold value $n_{th}$ for $\phi$ to increase. To meet this, the current density J must attain $J_{th}$. At just $n = n_{th}$, $\phi = 0$. Thus eqn ② reduces to : $\frac{n_{th}}{\tau_{sp}} = \frac{J_{th}}{qd}$ ← eqn ④ | → 2 marks |
| | At steady state operation of the laser, eqn ① & ② reduce to $0 = Cn_{th}\phi_s + R_{sp} - \frac{\phi_s}{\tau_{ph}}$ ← eqn ⑤ ; $0 = \frac{J}{qd} - \frac{n_{th}}{\tau_{sp}} - Cn_{th}\phi_s$ ← eqn ⑥ | → 1 mark |
| | Adding eqn ⑤ & ⑥ and substituting for $\frac{n_{th}}{\tau_{sp}}$ from eqn ④, the expression for the no. of photons emission per unit volume at steady state is obtained as $\phi_s = \frac{\tau_{ph}}{qd}(J - J_{th}) + \tau_{ph}R_{sp}$ | → 2 marks. |

| Question Number | Solution | Marks Allocated |
|---|---|---|

**6 a)**




PIN photo detector circuit → 3 marks



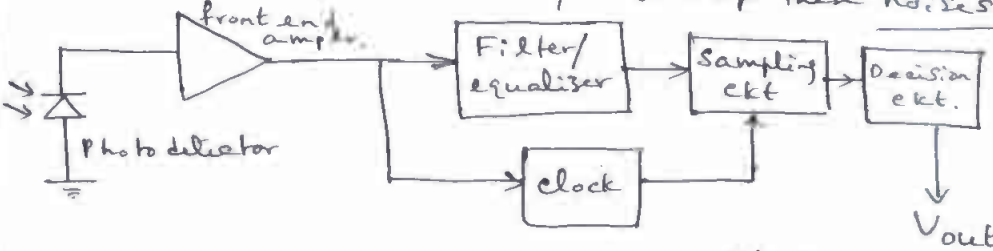

Exponential decay of optical power inside the PIN diode → 2 marks

Explanation of the phenomena & consequences that take place when light (photon energy) falls on the PIN photo detector to cause current flow → 3 marks

**6 b)** i) quantum noise (shot noise) ii) bulk dark current noise iii) surface dark (leakage) current noise → 3 marks

Explanation of source / origin of these noises → 1 mark X 3

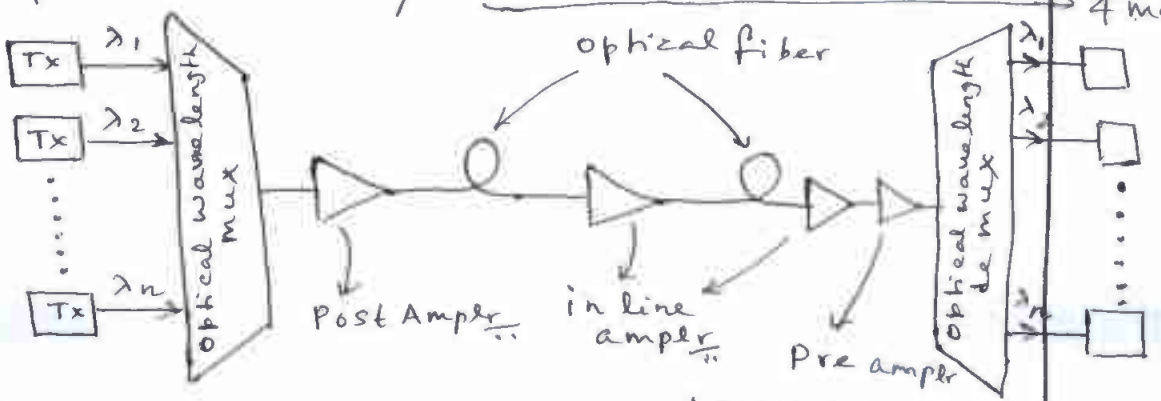
**6 c)**




Block diagram → 2 marks

Explanation of the functions and significance of each element/section → 4 marks.

**7 a)**



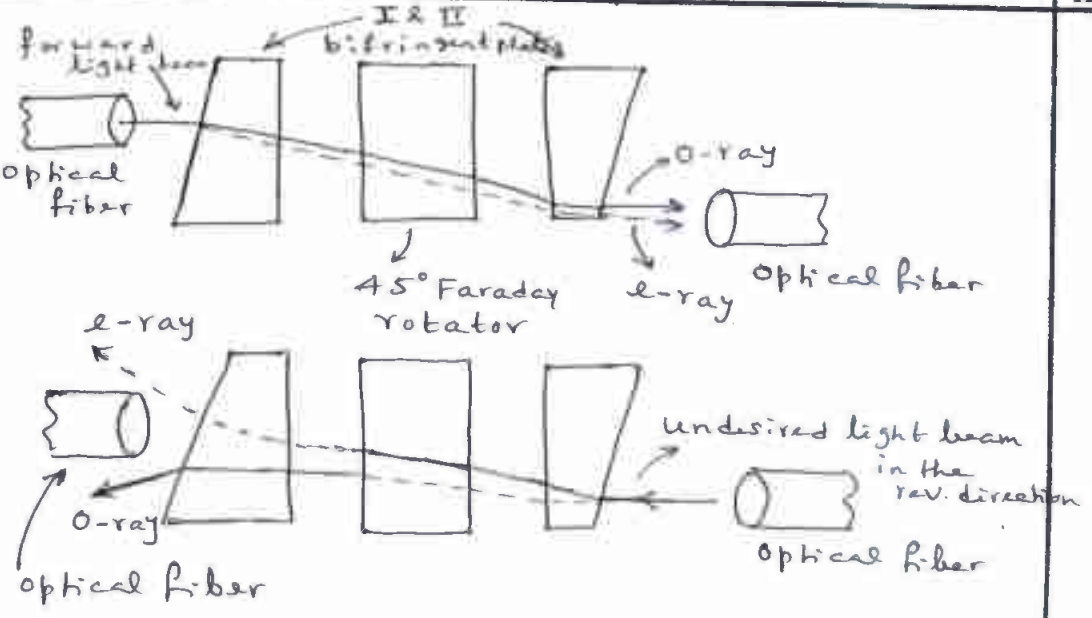

block diagram → 3 marks

Explanation of implementation & operational principle → 3 marks

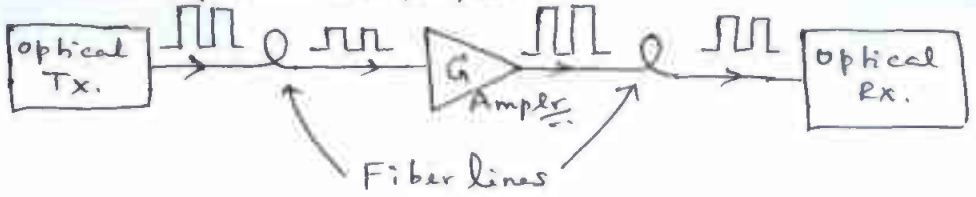
**7 b)** Explanation with constructional details and working → 3 marks.

Block diagram showing forward optical signal flow and blocking of reverse optical signal path → 3 marks

| Question Number | Solution | Marks Allocated |
|---|---|---|




7 c) i) In line optical amplifier :

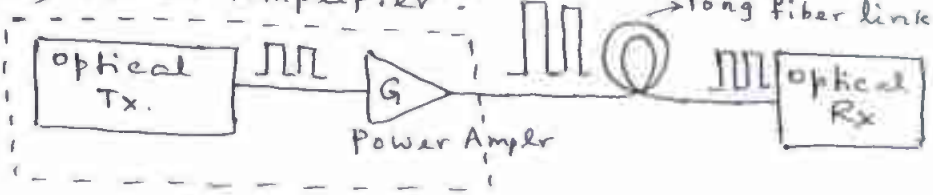


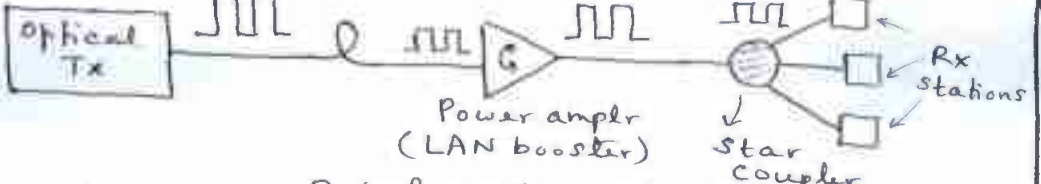

Brief explanation of use/application — 2 marks

ii) Pre-amplifier :


Brief explanation of use/application — 2 marks

iii) Power Amplifier :




Brief explanation of use/application — 4 marks

8 a)

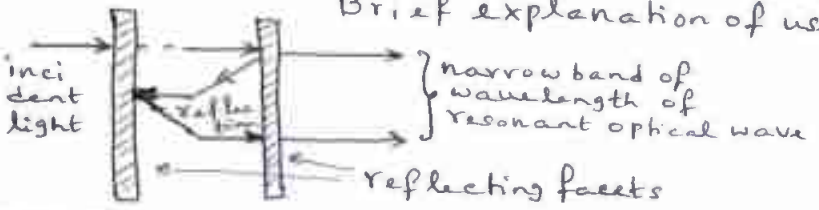



Diagram → 2 marks

Explanation of construction and Working → 4 marks

| Question Number | Solution | Marks Allocated |
|---|---|---|

8 b)

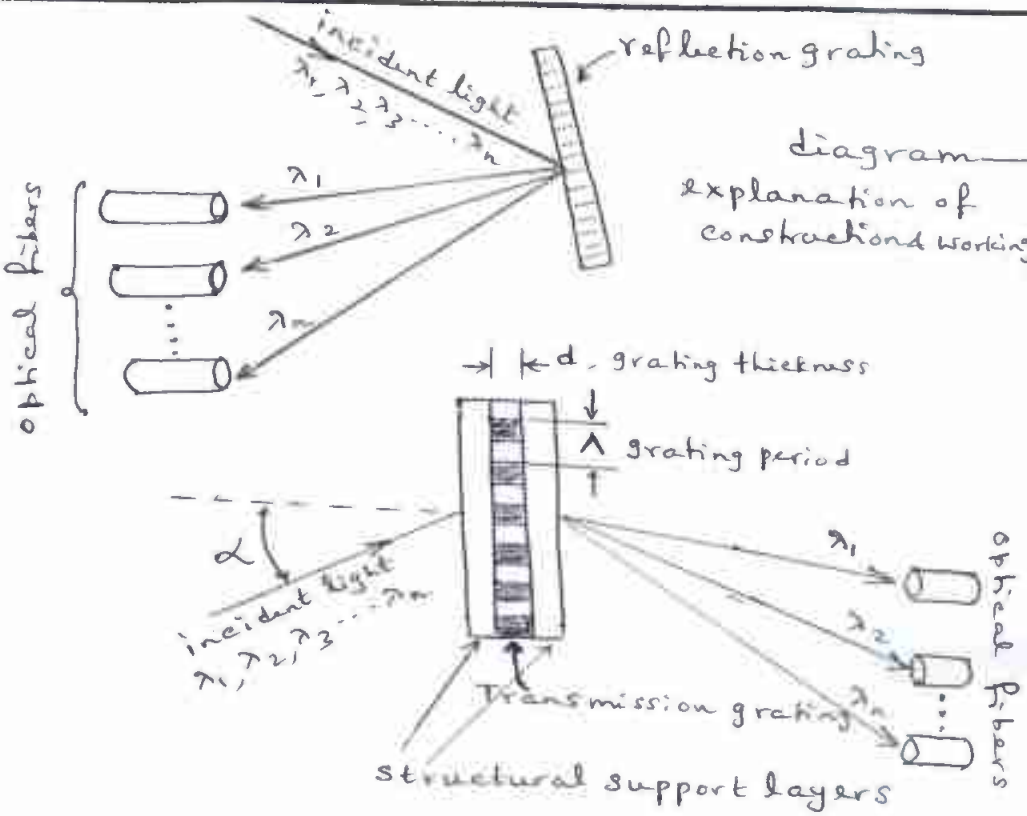



diagram → 2 marks
explanation of construction and working → 2 marks

8 c)

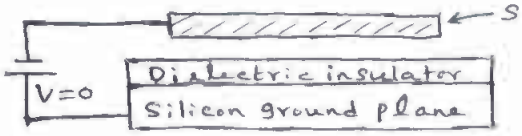



Diagram of MEMS actuation OFF → 2 marks

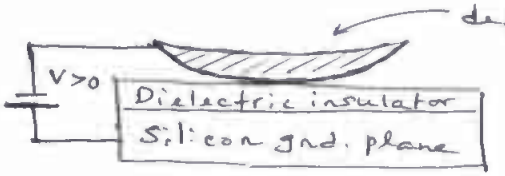



Diagram of MEMS actuation ON → 2 marks

9 a)

Explanation of operation → 2 marks

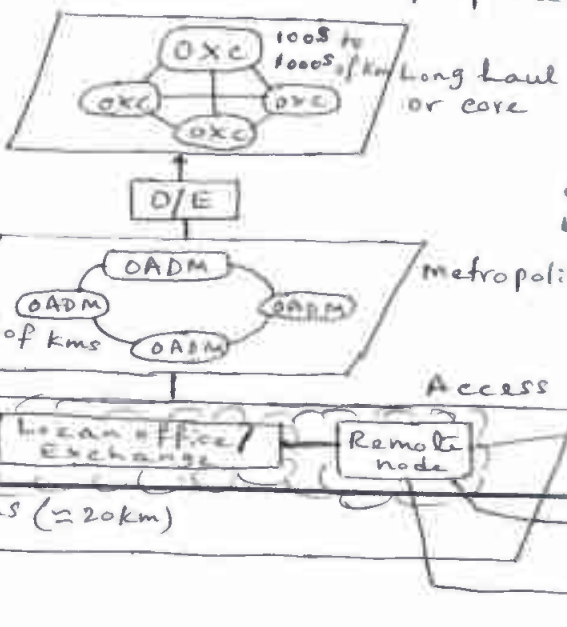



diagram → 3 marks
Explanation → 4 marks

| Question Number | Solution | Marks Allocated |
|---|---|---|

**9 b)**

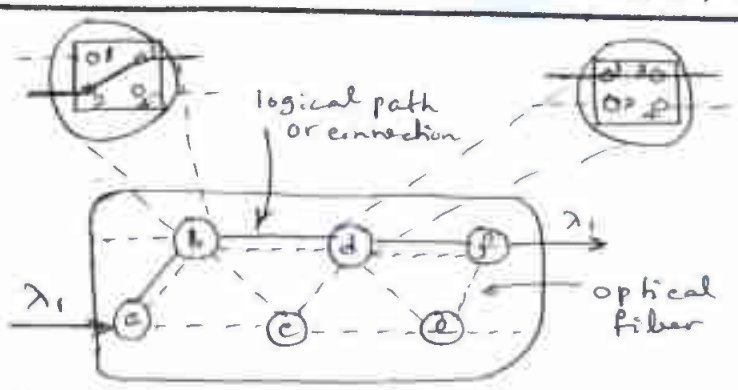
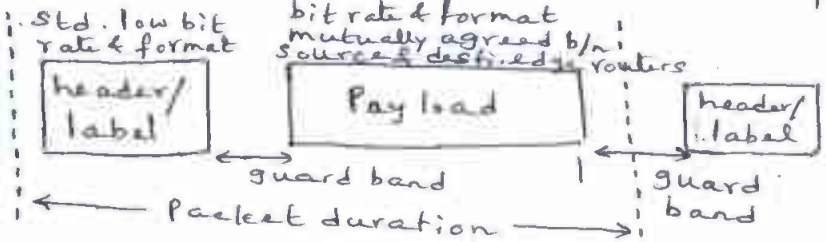



Diagram → 2 marks
explanation → 4 marks

**9 c)** i) Application layer ii) presentation layer iii) session layer iv) Transport layer v) Network layer vi) Data link layer vii) Physical layer — explanation of the functions and significance of each layer — 1 mark X 7

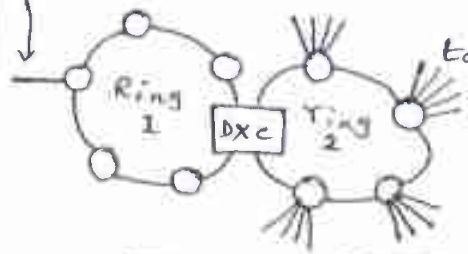
**10 a)**




i) routing
ii) forwarding
iii) switching
iv) buffering
— 2 marks

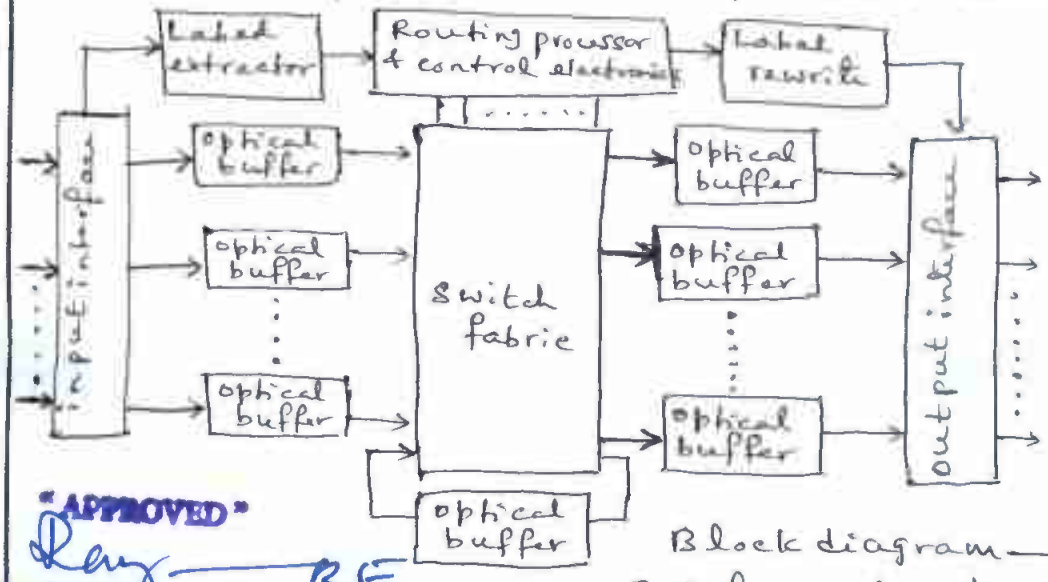
format diagram → 2 marks
Brief explanation of the format → 3 marks

**10 b)**




Structural diagram → 2 marks
Explanation → 4 marks

**10 c)**

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Block diagram → 4 marks
Brief explanation → 3 marks