DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
K.S.R. COLLEGE OF ENGINEERING: TIRUCHENGODE – 637 215.
COURSE / LESSON PLAN SCHEDULE

NAME : A.JAYAMATHI **CLASS: IV ECE A , B**
SUBJECT CODE AND NAME : 16EC712 & FIBER OPTICAL COMMUNICATION

TEXT BOOKS

1. John M. Senior ,"Optical Fiber Communication", Pearson Education ,3rd Edition, 2013
2. Gerd Keiser, "Optical Fiber Communication", Mc Graw Hill, 4th Edition. 2010

REFERENCES

1. GovindP.Agrawal, "Fiber-optic communication systems", John Wiley & sons. 4th Edition, 2010.
2. Harry J.R Dutton, "Understanding Optical Communications", IBM Corporation, International Technical Support Organization, 2012.
3. J.Gower, "Optical Communication System", Prentice Hall of India, 2nd Edition, 2003.
4. R.P.Khare, "Fiber Optics and Optoelectronics", Oxford University Press, 2007.

C). LEGEND:

L - Lecture
OHP - Over Head Projector
Tx - Text
BB - Black Board
pp - Pages
Rx - Reference

Sl. No	Lecture Hour	Topics to be covered	Teaching Aid Required	Book No./Page No
UNIT I - OPTICAL FIBER WAVEGUIDES				
1	L1	Introduction and Ray theory transmission	BB	$T_{X1/PP}$ 12-14, $T_{X2/PP}$ 26-31, $R_{X1/PP}$ 1-7, $R_{X3/PP}$ 33-36
2	L2	Characteristics of Light-Total internal reflection, Acceptance angle	BB	$T_{X1/PP}$ 14-20, $T_{X2/PP}$ 32-35 $R_{X3/PP}$ 35-36
3	L3	Numerical aperture , Skew rays	BB	$T_{X1/PP}$ 14-20,$T_{X2/PP}$ 32-35, $R_{X3/PP}$ 36-37
4	L4	Electromagnetic mode theory of optical propagation -EM waves ,Modes in Planar guide	BB	$T_{X1/PP}$ 24-28, $R_{X3/PP}$ 46-49 $R_{X1/PP}$ 28-36
5	L5	Phase and group velocity	BB	$T_{X1/PP}$ 103-104,$R_{X3/PP}$ 69-70
6	L6	Cylindrical fibers- modes, mode coupling step index fiber, graded index fiber	BB	$T_{X2/PP}$ 35-53 $R_{X3/PP}$ 40-46 $R_{X1/PP}$ 23-27
7	L7	SM fibers – cutoff wavelength, mode field diameter and spot size	BB	$T_{X1/PP}$ 54-71, $T_{X2/PP}$ 62-65 ,$R_{X3/PP}$ 34-40,190-195
8	L8	Fiber Attenuation measurements- Total fiber attenuation, Fiber absorption loss measurement, Fiber scattering loss measurement	BB	$T_{X1/PP}$ 909-918
9	L9	Fiber Numerical Aperture Measurements, Fiber diameter measurements, **Photonic crystal fibers**	BB	$T_{X1/PP}$ 938-943, $R_{X1/PP}$ 40-42
UNIT II- SIGNAL DEGRADATION IN OPTICAL FIBERS				
10	L10	Attenuation and Material absorption losses in silica glass fibers	BB	$T_{X1/PP}$ 88-90,90-95 $T_{X2/PP}$ 90-94,93-97. $R_{X3/PP}$ 89-93, $R_{X1/PP}$ 56-57
11	L11	Linear and Non linear Scattering losses	BB	$T_{X1/PP}$ 96-97 $T_{X2/PP}$ 97-101, $R_{X3/PP}$ 93-98, $R_{X1/PP}$ 57-63
12	L12	Fiber Bend losses and Midband and farband infrared transmission	BB	$T_{X1/PP}$ 100-101,100-102,103-105 $T_{X2/PP}$ 105-106

13	L13	Intra and inter Modal Dispersion and Over all Fiber Dispersion	BB	$T_{X1/PP}$ 109-113,124-131,$T_{X2/PP}$ 113-115-107, $R_{X1/PP}$ 41-43, $R_{X3/PP}$ 157-159,180-181
14	L14	Polarization, non linear effects	BB	$T_{X1/PP}$ 140-148, 51-154, $T_{X2/PP}$ 105-110, $R_{X1/PP}$ 64-67
15	L15	Optical fiber connections: Fiber alignment and Joint Losses	BB	$T_{X1/PP}$ 243-250,219-232, $T_{X2/PP}$ 231-235, 215-223$R_{X1/PP}$ 152-153, $R_{X3/PP}$ 231-236
16	L16,L17	Fiber Splices and Fiber connectors	BB	$T_{X1/PP}$ 233-241, $T_{X2/PP}$ 115-121, $R_{X3/PP}$ 230-236
17	L18	Fiber Couplers, **Optical isolators and circulators**	BB	$T_{X1/PP}$ 251-255,280-283,$R_{X2/PP}$ 256-259 $R_{X3/PP}$ 236-239
UNIT III – OPTICAL SOURCES				
18	L19,L20	Optical sources: Light Emitting Diodes - LED structures -Surface and edge emitters , Mono and hetero structures	BB	$T_{X1/PP}$ 396-410,$T_{X2/PP}$ 150-153, $R_{X3/PP}$ 258-259, $R_{X1/PP}$ 87-91,
19	L21	Internal quantum efficiency of LED	BB	$T_{X1/PP}$ 412-419,342-349,$T_{X2/PP}$ 153-154, $R_{X3/PP}$ 211-212
20	L22	Laser diode: Fabry-Perot laser, Distributed feedback laser	BB	$T_{X2/PP}$ 161-171, $R_{X1/PP}$ 94-99
21	L23	Injection laser diode structures , Comparison of LED and ILD	BB	$T_{X2/PP}$ 171-176, $R_{X3/PP}$ 361-372
22	L24	Modulation of laser diodes, Temperature effects	OHP	$T_{X2/PP}$ 168-172 $T_{X2/PP}$ 174-175
23	L25	Power launching and coupling: Source to fiber power launching	BB	$R_{X3/PP}$ 118-121 $T_{X2/PP}$ 191-196
24	L26	Lensing scheme for coupling improvement	BB	$T_{X2/PP}$ 196-199, $T_{X1/PP}$ 419-421
25	L27	LED coupling to SM fibers, **Optical sensor system**	BB	$T_{X2/PP}$ 208-209 $T_{X2/PP}$ 392-399 $T_{X1/PP}$ 866-870
UNIT IV- OPTICAL RECEIVER				
26	L28	Optical detectors: PIN photo detector, Schottky barrier photodiodes	BB	$R_{X3/PP}$ 138-141, $T_{X2/PP}$ 223-226, $T_{X1/PP}$ 432-434
27	L29	Avalanche photodiodes- Construction and properties	BB	$R_{X3/PP}$ 142-147,$T_{X2/PP}$ 227-230, $T_{X1/PP}$ 441-442
28	L30	Photo detector: noise sources, signal to noise ratio	BB	$R_{X3/PP}$ 155-158,$T_{X2/PP}$ 231-234 $T_{X1/PP}$ 502-505
29	L31	Detector response time, Comparison of photo detector	BB	$T_{X2/PP}$ 235-239
30	L32	Fundamental receiver operation: Digital Signal Transmission, Error sources	BB	$T_{X1/PP}$ 503-505,$T_{X2/PP}$ 275-281,
31	L33,L34	Front end amplifier: Pre amplifiers – high impedance FET amplifier	BB	$T_{X1/PP}$ 524-525,$T_{X2/PP}$ 305-308
32	L35	Bipolar, trans impedance amplifier		$T_{X1/PP}$ 526-530,$T_{X2/PP}$ 309-311
33	L36	Probability of Error and Quantum limit, **Optical packet switching**	BB	$T_{X2/PP}$ 281-289 $R_{X3/PP}$ 524-526 $T_{X2/PP}$ 493-494 $T_{X1/PP}$ 1000-1002
UNIT V – DIGITAL TRANSMISSION SYSTEMS				
34	L37	Point to point links : system consideration	BB	$R_{X3/PP}$ 183-185,$T_{X2/PP}$ 284-286
35	L38	Link power budget	BB	$T_{X2/PP}$ 286-288
36	L39	Rise time budget, problems	BB	$R_{X3/PP}$ 192-193 $T_{X2/PP}$ 289-292

37	L40	Noise effects in system performance	BB	$T_{X2/PP}$ 297-304, $T_{X1/PP}$ 122-124
38	L41	Operational principles of WDM	BB	$R_{X3/PP}$ 339-360 $T_{X2/PP}$ 341-345 $T_{X1/PP}$ 976-978
39	L42	Solitons & problems	BB	$R_{X3/PP}$ 404-410, $T_{X2/PP}$ 442-449 $T_{X1/PP}$ 792-801
40	L43	Erbium doped Fiber amplifiers	OHP	$R_{X3/PP}$ 250-260, $T_{X2/PP}$ 400-407
41	L44	Basics of SONET/SDH	OHP	$T_{X2/PP}$ 467-475
42	L45	**Optical time domain Reflectometre**	BB	$T_{X2/PP}$ 535-540, $T_{X1/PP}$ 952-958

UNIT I – OPTICAL FIBER WAVEGUIDES

TWO MARKS

1. **Define acceptance angle and critical angle of the fiber. (CO1)(Remembering)(MAY/JUNE 2009, May 2010,Nov 2012,Nov/Dec 2014,June 2018)**
   Acceptance angle : The acceptance angle is the maximum angle to the fiber axis at which light may enter the fiber axis in order to be propagated. $\Theta_{in(max)} = \mathrm{Sin}^{-1}\sqrt{(n_1^2-n_2^2)}$
   Critical angle : The critical angle is the angle of incidence that causes the refracted light to travel along the interface between two different mediums. $\Theta_c = \mathrm{Sin}^{-1}(n_2/n_1)$
2. **Why do we prefer step index single mode fiber for long distance communication? (CO1) (Remembering) (NOV 2011)**
   Step index single mode fiber has i) low attenuation due to smaller core diameter ii) higher bandwidth and iii) very low dispersion.
3. **What is V number of fiber or normalized frequency of fiber? (CO1) (Remembering) (Nov/Dec 2010), (Nov 2013)**
   V number of fiber or normalized frequency of fiber is used to find the number of propagating modes through the fiber. $V= 2\,\Pi\, a\,(N.A)/\lambda$
   In step index fiber number of modes propagating through the fiber=$V^2/2$. Taking the two possible polarizations, total number of possible modes propagating through the fiber= $(V^2/2)*2 = V2$
4. **Write short notes on: total internal reflection? (CO1) (Understanding) (Nov/Dec 2010) (Dec/Jan 2017)**
   i)Light should travel from denser medium to rarer medium. ii) The angle of incidence should be greater than the critical angle of the denser medium.
5. **What are the advantages of single mode fiber over multimode fiber? (CO1) (Remembering) (Nov 2012),(Apr/May2008,Nov/Dce 2014) (Dec/Jan 2017)**
   i.Very low attenuation ii. High quality signal transfer because of absence of modal noise iii. Largest available bandwidth distance product.
6. **Calculate the cutoff wavelength of a single mode fiber with core radius of 4µm and Δ = 0.003. (CO1) (Understanding) (Nov/Dec 2012)**
   Cut off wavelength $\lambda_c = 2\pi a n_1(2\Delta)^{1/2}/V_c$ for single mode V_c =2.405 and n_1=1
   $\lambda_c = 2*3.14*4*1*(2*0.003)^{1/2} / 2.405 = 0.809\mu m$
7. **What is the energy of a single photon of the light whose λ = 1550 nm, in eV? (CO1) (Remembering) (Nov/Dec 2011)**
   $\lambda= 1.240/E_g(eV) =1.240/1550 \times 10^{-3} =0.8eV$
8. **Assume that there is a glass rod of refractive index 1.5, surrounded by air.Find the critical incident angle. (CO1) (Applying)(Nov/Dec 2011)**
   $\Phi c=\sin^{-1}(n2/n1) = \sin^{-1}(1.5/1.0)= 0.66$
9. **A typical relative refractive index difference for an optical designed for long distance transmission is 1%. Estimate the numerical aperture for the fiber when the core index is 1.46.Find the critical angle at the core cladding interface within the fiber. (CO1) (Applying) (May/June 2012)**
   Numerical aperture of fiber is given by $NA = n1\sqrt{2\Delta} = 1.47\sqrt{2 X .01} = 0.21$
   Critical angle $\phi c = \sin\text{-}(n2/n1)$ $n2=(n1^2-NA^2)^{1/2} = 1.4448$ $\phi c = 81.9$
10. **Define a fiber- optic system. (CO1) (Remembering)**
    Fiber – optic system is nothing but a fiber-optic cable is essentially light pipe that is used to carry a light beam from one place to another.

11. Write the advantages of fiber –optic cables over conventional cables. (CO1) (Remembering)

The primary advantage of fiber –optic cables over conventional cables and radio are wider bandwidth, lower loss, light weight, small size, strength, security, interference immunity and safety.

12. Mention the disadvantages of fiber-optic cables. (CO1) (Remembering)

The main advantages of fiber –optic cable is that its small size and brittleness makes more difficult to work with.

13. Write down the ranges of optical frequency. (CO1) (Understanding)

The frequency of the optical spectrum is in the range of $3x10^{11}$ to $3x10^{16}$Hz.This includes both infrared and ultraviolet as well as the visible parts of the spectrum. Light frequencies used in optical fiber communications systems are between $1x10^{14}$Hz and $4x10^{14}$Hz(100,000GHz to 400,000GHz).

14. Define a repeater. (CO1) (Remembering)

Repeater is nothing but a re-generator of the original signal which is affected by noise. It is not an amplifier.

15. What is the relationship between information capacity and bandwidth? (CO1) (Remembering)

The information –carrying capacity of any electronic communication system is directly proportional to bandwidth. Optical fiber cables have, for all practical purposes, an infinite bandwidth.

16. Contrast glass and plastic fiber cables. (CO1) (Understanding)

Fiber – optic cables are made from glass and plastic. Glass has the lowest loss but it brittle. Plastic is cheaper and more flexible, but has high attenuation.

17. Write down the wavelength regions corresponding to first, second and third windows. (CO1) (Remembering)

1.First window - 800to 900 nm
2.second window -1100 to 1350nm
3.Third window-1500 to 1650nm

18. For a low power optical signal which type of photo-diode can be used? Why? (CO1) (Understanding)

Avalanche photo diode since it has a greater sensitivity owing to an inherent internal gain mechanism (avalanche effect).

19. Define Numerical aperture of a step index fiber. (CO1) (Remembering) (APR/MAY 2005, may 2010,Nov 2012)

Numerical aperture (N.A) of the fiber is the light collecting efficiency of the fiber and is the measure of the amount of light rays that can be accepted by the fiber. It is equal to the sine of acceptance. $N.A=\sin\varphi_{max}=(n1^2-n2^2)^{1/2}$ where n1 and n2 are the refractive indices of core and cladding respectively.

20. What is meant by refractive index of a material? (CO1) (Remembering)

The amount of refraction is called the index of refraction (n) and is the ratio of the speed of light in air to the speed of light in the material.

Index of refraction(n)= Speed of light in air (c)/Speed of light in substance (v) .

21. What is the function of an optical receiver in an optical repeater? (CO1) (Remembering)

An optical receiver detects the optical signal and converts it to an electric signal, which is amplified, reshaped and sent to the electric input of the optical transmitter.

22. Write the advantages of optical communication. (CO1) (Remembering)

i).Small size and weight ii).Immunity to interface and crosstalk iii).High signal security iv).Low transmission loss v).System reliability and ease of maintenance. vi).Wide band width and greater information capacity.

23. Define refraction. (CO1) (Remembering)

Refraction is the bending of a light ray that occurs when the light rays pass from one medium to another.

24. Write a short note on a) Angle of incidence (b) Angle of reflection. (CO1) (Understanding)

Angle of incidence: The angle at which light strikes a surface with respect to the normal is called the angle of incidence. The angle of the incident light ray determines whether the ray will be reflected or refracted.

Angle of reflection: The angle at which light is reflected from a surface is called the angle of reflection. The law of reflection is usually expressed in the following form: The angle of incidence is equal to the angle of reflection. Angle of incidence =Angle of reflection

25. Mention any two limitations of fiber optical communications. (CO1) (Understanding)

(1) High initial cost: The initial cost of installation or setting up cost is very high compared to all other system.

(2)Joining and test process: Since optical fibers are of very small size. The fiber joining process is very difficult and costly. It requires skilled manpower.

26. Write the function of light sources. (CO1) (Understanding)

The light source has two main functions. 1)It generates the optical (light) signal. 2)It also gives modulation of the light wave carrier with information signal.

27. Mention the necessary conditions for TIR. (CO1) (Understanding)

Two necessary conditions for TIR to occur are: i)T he refractive index of first medium (n_1) must be greater than the refractive index of second one (n_2). ii)The angle of incidence of the ray exceeds the critical value($\phi_1 > \phi_c$) .

28. What is a step – index fiber? (CO1) (Remembering)

If the refractive index of the core in a fiber is uniform throughout and undergoes an abrupt change or step at the cladding boundary, it is called step index fiber.

29. What is a graded index fiber? (CO1) (Remembering)

If the refractive in a fiber is made to vary as a function of the radial distance from the center of the fiber, it is called graded – index fiber, i.e., refractive index decreases as the radial distance increases (moves away from the center)

30. What is order of a mode ? (CO1) (Remembering)

The order of a mode is equal to the number of field zeros across the guide.

31. Define a intermodal distortion. (CO1) (Understanding)

When an optical pulse is launched into a fiber, the optical power in the pulse is distributed overall of the modes of the fiber. Each of the modes that can propagate in a multimode fiber travels at a slightly different velocity. So the optical pulse arrive at the fiber end at slightly different times, thus causing the pulse to spread out in times as it travels along the fiber. That is called intermodal dispersion (or) Intermodal distortion.

32. What is meridional ray? (CO1) (Understanding)

Meridional rays are pass through the fiber (core) axis after each total internal reflection from the core cladding boundaries. Meridional ray lies in a single plane, its path is easy to track as it travels along the fiber.

33. On what laws the bounded rays get propagated? (or) What is bounded rays? (CO1) (Understanding)

The bounded rays that are trapped in the core and propagate along the fiber axis according to the laws of geometrical optics.

34. What are skew rays? (CO1) (Understanding) (Nov/Dec 2009)

Skew rays are the rays following the helical path around the fiber axis when they travel through the fiber and they would not cross the fiber axis at any time. It is very difficult to track the skew rays as they do not lie in a single plane.

35. What do you meant by modes? (CO1) (Understanding)

The modes are referred to the number of paths for the light rays in the fiber cable.

36. What is an index profile? (CO1) (Understanding)

The index profile of an optic fiber is a graphical representation of the magnitude of the refractive index across the fiber.

37. Define graded index fiber. (CO1) (Understanding)

The core refractive index is made to vary as a function of the radial distance from the center of the fiber. This type is a graded – index fiber. The index of refraction varies smoothly and continuously over diameter of the core.

38. What are unbound rays? (CO1) (Remembering)

The unbound rays that are refracted out of the fiber core.

39. Mention the names of different optical fiber configuration. (CO1) (Remembering)

Depending on the refractive index profile of fiber and modes of fiber, three configurations are commonly used. This optic – fiber configuration are i)Single mode step – index fiber ii)Multimode step - index fiber iii)Multimode graded index fiber

40. What is ray theory approach? (CO1) (Remembering)

A ray of light is the one dimensional approach and indicates the direction of propagation of light through the fiber. The ray theory is otherwise known as tracing approach or geometrical optics representation.

41. Write the expression for the acceptance angle for skew rays. (CO1) (Understanding)

The acceptance angle for skew rays is expressed as $\Theta_a = \sin^{-1}(NA/\cos\gamma)$. At each reflection, the fiber will give a 2γ direction change for rays.

42. Define weakly guiding approximation. (CO1) (Remembering)

In a step index fiber the difference in the core and cladding indices of refraction is very small ($\Delta<<1$) . This is the basis of the weakly guiding fiber approximation. Usually Δ is less than 0.003 (3%) for optical communication.

43. What is linearly polarized mode? (CO1) (Understanding) (May/June 2013)

In a step index fiber the difference in the core and cladding indices of refraction is very small ($\Delta<<1$) . This is the basis of the weakly guiding fiber approximation. Usually Δ is less than 0.003 (3%) for optical communication. With this weakly guiding assumption, only four field components (HE,EH,TE and TM) need to be considered and their expressions become significantly similar. The field components are called linearly polarized components.

44. What is degenerate modes? (CO1) (Remembering)

In weakly guiding fibers Δ is small , then HE-EH mode pairs occur which have almost identical propagation constants and electromagnetic field patterns. Such modes are said to be degenerate.

45. What are TE modes? (CO1) (Remembering)

Consider electromagnetic waves propagating along the cylindrical fiber. If the axis of the fiber lies along the z-axis of the cylindrical co-ordinate system when $E_z = 0$, the modes are called transverse electric (TE) modes.

46. Write the expression for the total number of guided mode supported by the graded index fiber. (CO1) (Understanding)

The total number of the guided modes or mode volume M supported by the graded index fiber is given by $M= (\alpha / \alpha+2)\ (n_1ka)^2\ \Delta$ Where, r is the radial distance from the fiber axis, a is the core radius, n_1 is the refractive index at the core axis, n_2 is the refractive index of the cladding and α is the profile parameter which gives the characteristic refractive index profile of the fiber core and Δ is the refractive index index difference.

47. What are TM modes? (CO1) (Remembering)

When $H_Z=0$, the modes are called transverse magnetic (TM) modes.

48. What is meant by mode coupling? (CO1) (Remembering)

Mode coupling is the coupling of energy from one mode to another arises.

49. Why single mode fiber is widely used in telecommunication? (CO1) (Understanding)

1).Single mode fiber utilize transmission bandwidth effectively and have lowest losses in the transmission medium. 2).They have a superior transmission quality over other fiber types because of the absence of modal noise. 3).They offer a substantial upgrade capability for future wide bandwidth services using either faster optical transmitters and receivers or advanced transmission techniques. 4).They are compatible with the developing integrated optics technology. 5).The installation of single-mode fiber will provide a transmission medium which will have adequate performance such that it will not require replacement over its twenty-plus anticipated li

50. What are the factors involved in the mode coupling? (CO1) (Understanding)

The coupling of energy from one mode to another arises because of

i) Structural imperfections ii)fiber diameter variations iii)Refractive-index variations iv)Cabling-induced micro bends and v)-Irregularities at core-cladding interference.

51. Write the expressions that support the single mode operation in a graded index fiber? (CO1) (Understanding)

The cutoff value of normalized frequency V_c to support a single mode in a graded index fiber is given by $V_c = 2.405(1+2/\alpha)^{1/2}$ Using this expression, it is possible to determine the fiber parameters which give single-mode operation.

52. What is mode field diameter? (CO1) (Remembering)(APR/MAY 2004), (Nov/Dec 2010)

The Mode Field Diameter (MFD) is an important parameter for characterizing single mode fiber properties which takes into account the wavelength dependent field penetration into the fiber cladding. This parameter can be determined from the mode – field distribution of the fundamental LP_{01} mode.

53. Define effective refractive index. (CO1) (Remembering)

Effective refractive index for single-mode fiber is defined by the ratio of the propagation constant of the fundamental mode to the vacuum propagation constant $n_{eff} = \beta/k$

54. What are hybrid modes? (CO1) (Remembering)

When both H_z and E_z are non-zero , the modes are called hybrid modes. These are designated as EH or HE modes, depending on whether H_z or E_z makes a larger contribution to the transverse field.

55. Mention the advantage of multimode fibers over single mode fiber. (CO1) (Remembering) (May/June 2013)

Multimode fibers have several advantages over single mode fibers:

1).the use of spatially incoherent optical sources(eg. LED's) which cannot be effectively coupled to single mode fibers.2).Larger numerical apertures as well as core diameters, facilitating easier coupling to optical sources.3).Lower tolerance requirements on fiber connectors.

56. Write the expression for the refractive index in graded index fibers. (CO1) (Understanding)(APR/MAY 2004,June 2016)

$n(r)= n_1[1-2\Delta(r/a)^{\alpha}]^{1/2}$ for $0 \leq r \leq a$

$n1(1-2\Delta)^{1/2} \approx n1(1-\Delta) = n2$ for $r \geq a$

r - radial distance from fiber axis , a - core radius ,n1 - refractive index at the core axis , n2 - refractive index at the cladding, α - shape of the index profile, Δ - index difference

57. Give the expression for linearly polarized waves. (CO1) (Understanding)

The electric or magnetic field of a train of plane polarized waves travelling in a direction k can be represented in the general form $A(x,t) = e_i Aoexp[j(wt-k.x)]$ with $x=xe_x+ye_y+ze_z$ representing a general position vector and $k=kxe_x+kye_y+kze_z$ representing the wave propagation vector.

58. What are the advantages and disadvantages of the ray optics theory. (CO1) (Understanding)((NOV/DEC 2008)

Advantages: i. It gives more direct physical interpretation of light propagation characteristics in an optical fiber. ii. Good approximation methods to the light acceptance and guiding in fiber in small Wavelength unit.

Disadvantages: i. Ray optics does not predict every mode of cure fiber. ii. It does not solve the interference problem. iii. Inaccurate for non- zero wavelength unit when number of guided mode is large.

59. What is Snell's law? (CO1) (Remembering)

The relationship at the interface is known as Snell's law and is given by $n_1 \sin\varphi_1 = n_2 \sin\varphi_2$

60. What is the necessity of cladding for an optical fiber? (CO1) (Understanding)(Dec 2015,June 2016,May 2019)

i) To provide proper light guidance inside the core ii) To avoid leakage of light from the fiber iii) To avoid mechanical strength for the fiber iv) To protect the core from scratches and other mechanical damages

61. What are the uses of optical fibers? (CO1) (Understanding)

i) To transmit the information which are in the form of coded signals of the telephone communication, computer data, etc. ii) To transmit the optical images (Example : Endoscopy) iii) To act as a light source at the inaccessible places. iv) To act as sensors to do mechanical, electrical and magnetic measurements.

62. What is the principle used in the working of fibers as light guides? (CO1) (Understanding)

The phenomenon of total internal reflection is used to guide the light in the optical fiber. To get total internal reflection, the ray should travel from denser to rarer i.e. from core to cladding region of the fiber and the angle of incidence in the denser medium should be greater than the critical angle of that medium.

63. Relate between numerical aperture of skew rays and meridional rays. (CO1) (Understanding)

$(N.A)_{skew} = \cos\gamma (N.A)_{meridional}$ when the fiber is placed in air. Here γ is the half of the angular change in every reflection.

64. What is fiber birefringence and fiber beat length? (CO1) (Understanding) (MAY/JUNE 2009)

Fiber birefringence: The modes propagate with different phase velocities, and the difference between their effective indices is called the fiber birefringence. $B_y = n_y - n_x$

Fiber beat length: If light is injected into the fiber so that both modes are excited, one mode is delayed in phase relative to the order as they propagate. When the phase difference between two modes is an integral multiple of 2π, the modes will beat at this point and the input polarization will be reproduced. The length over which the beating occurs is known as fiber beat length. $Lp = 2\pi / \lambda$

65. Give the expression for numerical aperture in graded index fibers. (June 2016)(CO1) (Understanding)

N.A(r)=N.A.(0) (1-(r/a) $^{\alpha}$)1/2 for r ≤ a where N.A(0) = axial numerical aperture = $(n_1^2-n_2^2)^{1/2}$ a- is core radius and α is the refractive index profile.

66. Give the relationship between rays and modes. (CO1) (Understanding) (NOV/DEC 2007)

Ray gives the direction of travel of a plane wave. A guided mode travelling in the z direction along an optical fiber can be decomposed into a family of plane waves. Since with each plane wave, a light ray can be associated, the family of plane waves corresponding to a mode forms a set of rays called ray congruence.

67. A silica optical fiber has a core refractive index of 1.5 and a cladding refractive index of 1.47.Determine the Numerical aperture, acceptance angle and critical angle in air for the fiber. (CO1) (Applying)(NOV/DEC 2007),(Apr/May 2008) (Nov 2013),(May/June 2013)(Dec 2015)

Given : n_1 = 1.5 and n_2 = 1.47 NA = $(n_1^2-n_2^2)^{1/2}$ = 0.3 Acceptance angle = $\sin^{-1}$(NA) = 1.74°
Critical angle= $\sin^{-1}$(n2/n1)= $\sin^{-1}$(1.47/1.5) = $\sin^{-1}$ (0.98)

68. A typical relative refractive index difference for an optical designed for long distance transmission is 1%. Estimate the numerical aperture for the fiber when the core index is 1.47. (CO1) (Applying)(NOV/DEC 2008), (Nov/Dec 2012)

Numerical aperture of fiber is given by NA = n1 $\sqrt{2\Delta}$ = 1.47 $\sqrt{2\ X\ .01}$ = 0.2

69. A multimode step index fiber with a core diameter of 80 μm and a relative index difference of 1.5% is operating at a wavelength of 0.85 μm. If the core refractive index is 1.48, estimate the normalized frequency for the fiber and the number of guided modes. (CO1) (Applying)(April/May 2010), (May/June 2012)(Dec 2014)

i. Normalized frequency (V) = $\frac{2\pi a}{\lambda} n_1\sqrt{2\Delta}$ =(2 X 3.14 X 40 / 0.85) X 1.48 x$\sqrt{2\ X\ .015}$ =75.8

ii. Number of guides modes (M) = ½ V^2 = ½ $(75.8)^2$ = 2873

70. An optical fiber in air has an NA of 0.4. Find the acceptance angle for meridional rays? (CO1) (Applying)

Acceptance angle $\theta_a = n_0 \sin^{-1}$NA , n_0 = 1 for air, $\theta_a = n_0 \sin^{-1}$ NA = $\sin^{-1}$ 0.4 = 23.6°

71. A single mode fiber has a beat length of 9 cm at 1300nm. Find the birefringence of the fiber. (CO1) (Applying)(Nov/Dec 2010)

Birefringence of the fiber $\beta = \frac{2\pi}{L_p} = \frac{2\pi}{0.09\ m}$ = 69.7cm^{-1}

72. What is tunnel effect in optical fiber? (CO1) (Understanding)(Nov/ Dec 2009)

The leaky modes are continuously radiation their power out of the core as they propagate along the fiber. This power radiation out of the waveguide in quantum mechanical phenomenon is referred to as tunnel effect.

73. List the important requirements to be satisfied while selecting materials for optical fiber? (CO1) (Evaluating)(Nov2012)

i.It must be possible to make long, thin, flexible fibers from the material.ii.The material must be transparent at a particular optical wavelength in order for the fiber to guide light efficiently.
iii.Physically compatible materials that have slightly different refractive indices for the core and cladding must be available.

74. Calculate the numerical aperture and solid acceptance angle in air for a fiber with core refractive index of 1.46 and core cladding index difference Δ= 0.01(CO1) (Applying)(May/June 2013)

NA = n1$(2\Delta)^{1/2}$ =1.46 $(2*0.01)^{1/2}$ =0 .2064

75. What is need of fiber attenuation measurements techniques ?(Analayzing)

Fiber attenuation measurement techniques are used in order to determine the total fiber attenuation loss due to both absorption losses and scattering losses.

76. Mention the names of different techniques used for determining attenuation in fiber. (Remembering)

For determining attenuation in fibers three major techniques are used (i)Cutback technique (ii)Insertion loss method (iii)Optical Time Domain Reflectometers (OTDR)

77. Write expression for the measurements of attenuation in cutback method. (Remembering)

Let PF and PN represent the output power at far and near ends of the fiber, respectively .Then the attenuation α in decibels per kilometer is expressed as

α =10/L log P_N/P_F, where ,L is the separation distance of two measurement points (km)

78. **Write the importance of the refractive index profile measurements.(Understanding)**

    i.The refractive index profile of the fiber core plays an important role in characterizing the properties of optical fibers.

    ii.It allows determination of the fiber's numerical aperture on the number of modes propagating within the fiber core.

79. **What are the common methods used for determination of fiber NA?(Understanding)**

    Commonly used techniques for determination of fiber NA are i. Measurement of the far field radiation pattern from the fiber ii. Far field pattern by trignometric mean.

80. **State the significance of maintaining the fiber outer diameter constant. (Analyzing) (Nov/Dec 2014)**

    i)Outer diameter is constant within 1% ii)Speed is large iii)More accuracy

81. **What are the methods used to measure fiber refractive index profile? (Remembering) (May/June 2012)**

    i.Interferometeric method ii.Near field scanning method iii. Refractive near field method

<u>16 MARKS</u>

1. Discuss mode theory of circular waveguides. (CO1) (Creating)(NOV/DEC 2004),(Nov/Dec 2009),(Nov/Dec 2013,Nov/Dec 2014)(Dec 2015, June 2018)
2. Discuss the theory of Graded Index Fibers. Derive the expression for the numerical aperture of Graded Index Fiber. (CO1) (Creating)(NOV/DEC 2004),(Nov/Dec 2013), (May/June 2012), (May/June 2013),(Nov/Dec2014)
3. i. Discuss the propagation modes in single – mode fiber. ii. Discuss the structure of graded index fiber. (CO1) (Creating)(APR/MAY 2005)
4. Derive an expression for number of modes propagating in a graded index fiber from the first principle. (CO1) (Understanding)(Apr/May2008)
5. i.Derive an expression for numerical aperture of a step Index fiber.(Understanding) ii. The relative refractive index difference between the core axis and the cladding of a graded index fiber is 0.7% when the refractive index at the core axis is 1.45. Estimate values for the numerical aperture of the fiber along the axis when the index profile is assumed to be triangular. (CO1) (Apr/May 2008),(Applying)(apr/May 2010) (May/June 2013)
6. i.Briefly explain the evolution of fiber optic system. ii. Compare the configurations of different types of fibers. (CO1) (Understanding)(NOV/DEC 2005)
7. i. Derive modal equation. ii. Discuss the modes in step – index fibers.(Creating) (CO1) (NOV/DEC 2005)
8. i. List the advantages of optical fiber communication. ii. Draw the elements of an optical fiber transmission link and explain. (CO1) (Remembering) (MAY/JUNE 2006, Nov 2012),(Nov/Dec 2013),(Nov/Dec 2009), (Nov/Dec 2008) (Dec 2015,MAY 2019)
9. Explain mode propagating in circular waveguides. Obtain its wave equation and modal equations for step index fibers. (CO1) (Understanding) (MAY 2010)
10. i)What is numerical aperture of an optical fiber? Deduce an expression for the same. (ii) Calculate NA of silica fiber with its core refractive index (n1) of 1.48 and cladding refractive index of 1.46. What should be the new value of 'n1' in order to change the NA to 0.23. (CO1) (Applying) (Nov/Dec 2011)(Apr/May 2019)
11. i)Explain the phenomenon of total internal reflection using Snell's law with figures and calculations. (Evaluating) (ii) Distinguish step-index from graded index fibers. (CO1) (Analyzing) (Nov/Dec 2011, June 2018)
12. i.Starting from the Maxwell's equation, derive the expression for the wave equation of an electromagnetic wave propagating through optical fiber. ii.Derive the ray theory behind the optical fiber communication by total internal reflection. State the application of Snell's law in it. (CO1) (Understanding) (Nov/Dec 2012)
13. (i) A Si fiber with silica core refractive index of 1.458, v = 75 and NA = 0.3 is to be operated at 820nm. What should be its core size and cladding refractive index? Calculate the total number of modes entering this fiber. (ii) Derive expression for the linearly polarized modes in optical fibers and obtain the equation for V number. (CO1) (Applying) (Nov/Dec 2012)
14. i. Derive the wave equations for the step – index fiber and explain. ii. A step index fiber has normalized frequency 26.6 at a 1300 nm wave length. If the core radius is 25μm find the numerical aperture and mode volume. (Applying) iii. What is meant by weakly guiding

approximation? (CO1) (Remembering)

15. i. Discuss the major elements of an optical fiber transmission link. (Creating) ii. Briefly explain the various generations of the fiber optic communication. iii. Define Mode field Diameter and Birefringence. (CO1) (Remebering)
16. A typical relative refractive index difference for an optical designed for long distance transmission is 1%. Estimate the numerical aperture for the fiber when the core index is 1.47. (CO1) (Applying) (Apr /May 2010)
17. i. Explain with neat diagram the elements of an optic fiber transmission link. (CO1) (Understanding) (NOV 06),(Nov 13)
    ii. A multimode step index fiber with a core diameter of 80 μm and a relative index difference of 1.5% is operating at a wavelength of 0.85 μm. If the core refractive index is 1.48, estimate the normalized frequency for the fiber and the number of guided modes.Determine the number of guided modes if Δ is reduced to 0.003. (CO1) (Applying)(May/June 2012)
18. i. Sketch and explain the electric field distribution of the lower order guided modes in symmetrical slab waveguide. ii. Draw the structures of step index and graded index fibers with their typical dimensions. (CO1) (Understanding)(NOV/DEC 06)
19. i.Discuss briefly about linearly polarized modes. ii. Mention the advantages of optical fiber communication systems. (CO1) (Creating)(Nov/Dec 2009), (Nov/Dec 2012)
20. Explain optical laws ray optics theory. (CO1) (Understanding)
21. Explain the various fiber types, modes and its configuration. (CO1) (Analyzing)(Nov/Dec 10,Nov/Dec 2014)
22. Explain Key modal concept and Graded index fiber structure. (CO1) (Understanding)(Nov 2012)
23. With the help of suitable digrams, explain the following concepts in optical fiber communication.1.Evanescent field 2. Goos – Haenchen field shift 3. Mode coupling. (CO1) (Understanding)(Nov/Dec 09)
24. A multi mode GI fiber has an acceptance angle in air of 8^0 .Estimate the relative refractive index difference between the core axis and the cladding when refractive index at the core axis is 1.52. (CO1) (Applying)(Nov/Dec 09)
25. (i) Explain With Simple ray diagrams (1) the multimode SI fiber and (2) the single mode SI fiber. Compare the advantages and disadvantages of these two types. (CO1) (Evaluating)(Nov/Dec09)(Dec 2015)
26. A single mode step index fiber has core and cladding refractive index of 1.498 and 1.495 respectively. Determine the core diameter required for the fiber to permit its operation over the wavelength range 1.48 and 1.60 micro meter. Calculate the new fiber core diameter to enable single mode transmission at the wavelength of 1.3 micro meter. (CO1) (Applying)(Nov/Dec 09,Apr/May 2019)
27. Draw and explain the acceptance angle and numerical aperture of an optical fiber and drive expression for both. (CO1) (Remembering)(May/June 2012)
28. i.Explain the ray theory of fiber with special mention about TIR, acceptance angle and numerical aperture. Ii. Describe single mode fiber and their mode field diameter. (CO1) (Understanding)(May/June 2013)
29. (i) Starting from the Maxwell's equation, derive the expression for the wave equation of an electromagnetic wave propagating through optical fiber (ii) Derive the ray theory behind the optical fiber communication by total internal reflection. State the application of Snell's law in it. (CO1) (Understanding)(Nov/Dec 2012)
30. (i) A Si fiber with silica core refractive index of 1.458, v = 75 and NA = 0.3 is to be operated at 820nm. What should be its core size and cladding refractive index? Calculate the total number of modes entering this fiber (Applying) (ii) Derive expression for the linearly polarized modes in optical fibers and obtain the equation for V number. (CO1) (Remembering) (Nov/Dec 2012)
31. Write notes on the following (i) Fiber refractive index profile measurement (ii) Fiber cut off wavelength measurement iii. NA Measurement (Understanding) (Nov/Dec 2012),(Nov/Dec 2014)
32. i. Explain the insertion loss method used for attenuation measurement. ii. Explain the technique used in frequency domain intermodal dispersion measurements. (Understanding) (Nov/Dec 2013)
33. Explain the measurement technique used in the case of i. Numerical aperture ii. Refractive index profile iii. Fiber cut-off wave length iv. Fiber diameter.(Remembering)(Nov/Dec 2011)
34. Explain the following measurements i.Attenuation measurements using cut back techniques ii. Frequency domain measurement of fiber dispersion. (Understanding) (May/June 2012)

35. A multimode step index fiber with a core diameter of 80μm and refractive index difference of 1.5% is operating at a wavelength of 0.85μm.If core refractive index is 1.48 . Calculate 1) V-number 2)Number of guided modes.(Dec 2015)(CO1)(Applying)
36. Draw and explain the working of single mode fiber.(Dec 2015)(CO1)(Understanding)
37. What are the functions of Core and Cladding in an optical fiber? Why should their refractive indices be different? Would it be possible for light to be guided without cladding?(June 2016) (CO1) (Understanding)
38. Explain the concept of electromagnetic modes in relation to a planar optical waveguide. Discuss the modifications that may be made to electromagnetic mode theory in a planar waveguide in order to describe optical propagation in cylindrical fiber.(June 2016) (CO1) (Understanding)

UNIT II-SIGNAL DEGRADATION IN OPTICAL FIBERS

TWO MARKS

1. **Give the expression of the effective number of modes that are guided by a curved multimode fiber of radius 'α'. (CO2) (Understanding)(NOV/DEC 04)**

$$N_{eff} = N\infty \left\{1 - \frac{\alpha+2}{2\alpha\Delta}\left(\frac{2a}{R} + \left(\frac{3}{2n_2kR}\right)^{2/3}\right)\right\}$$

α - Graded index profile , Δ - core – cladding index difference n2 – refractive index of cladding, k = 2π/λ propagation constant, $N\infty = \frac{\alpha}{\alpha+2}(n_1 k a)^2$

2. **What are the causes of absorption? (CO2) (Remebering)(APR/MAY 05, June 2018,MAY2019)**

i). Absorption by atomic defects in the glass composition ii).Extrinsic absorption by impurity atoms in the glass material. iii). Intrinsic absorption by the basic constituent atoms of thefiber material.

3. **What causes mode coupling? (CO2) (Remembering)(MAY/JUNE 06)**

Mode coupling is the coupling of energy from one mode to another arises because of structural imperfections fiber diameter and refractive index variations and cabling induced micro bends.

4. **List the basic attenuation mechanism in an optical fiber. (CO2) (Remembering)(NOV/DEC 06)**

i. Absorption ii. Scattering iii.Radiative losses.

5. **What are the types of fiber losses which are given per unit distance? (CO2) (Understanding)(Nov/Dec 2014)**

i.Attenuation ii.Scattering losses iii. Bending losses iv.Dispersion

6. **What do you mean by polarization mode dispersion? (CO2) (Understanding)(NOV/DEC 06), (Nov/Dec 2010,2013) (Dec 2015)**

Signal energy at a given wavelength occupies two orthogonal polarization modes. Due to varying birefringence along a fiber, each polarization mode travel at a slightly different velocity. This difference in propagation times, results in pulse spreading. This is polarization mode dispersion.

7. **List the factors that cause intrinsic joint losses in a fiber. (CO2) (Understanding) (Nov/Dce 2014)**

i.Different core and/or cladding diameters ii.Different numerical aperture and/or relative refractive index difference iii.Different refractive index profiles iv. Fiber faults

8. **Distinguish dispersion shifted and dispersion flattened fibers. ((CO2) Analyzing)(NOV/DEC 07)**

Dispersion shifted fiber : By creating a fiber with large negative waveguide dispersion & assuming the same values for material dispersion as in a standard single mode fiber the addition of waveguide & material dispersion can then shifted to zero dispersion point to long wavelength. The resulting optical fiber is known as dispersion shifted fiber.

Dispersion flattened fiber: The reduction of fiber dispersion by spreading the dispersion minimum out over a wide range .This approach is known dispersion flattering.

9. **What is group delay? (CO2) (Remembering) (NOV/DEC 08),(Nov/Dec 2013)**

In an optical fiber there are various modes present. Then the optical input, which is propagated along the fiber, will travel in various modes. Because of these modes the velocity of the signal will vary also there may be a delay in the optical signal of these various modes. This is called as the 'Group Delay'. $\tau_g = \frac{L}{V_g} = \frac{\text{Distance travelled by pulse}}{\text{Group velocity}}$

10. A multi mode graded index fiber exhibits total pulse broadening of 0.1 µs over a distance of 15 km. Estimate the maximum possible bandwidth on the link assuming RZ coding without intersymbol interference. (CO2) (Applying)(NOV/DEC 08 & 09)

$\tau = 0.1\mu s$, L = 15 km, Maximum possible bandwidth $B_T = \frac{1}{2\tau} = \frac{1}{2 X 0.1} = 5$ MHz

11. A 100 km fiber is used in a communication system. The fiber has 3.0 dB/km loss. What will be the output power, when the input power fed at the input of fiber is 500 µW. (CO2) (Applying)

Total attenuation at 100 km fibers end = 100 X 3 dB/km = 300 dB

300 dB = 10 $\log_{10}\left(\frac{500 X 10^{-6}}{x}\right)$ x = output power i.e; $\log_{10}\left(\frac{500 X 10^{-6}}{x}\right) = 30$

x = output power i.e; $\log_{10}\left(\frac{500 X 10^{-6}}{x}\right) = 30$ x = 500 X 10^{-36} watts

12. What is the need for mode coupling in optical fiber? (CO2) (Remembering) (MAY/JUNE 08)

Pulse distortion will not increase because of mode coupling. Coupling of energy from one mode to another arises because of structural imperfections, fiber diameter, and refractive index variations and micro bends. Mode coupling tends to average out the propagation delays and thereby reduces intermodal dispersion.

13. Mention the two causes of intramodal dispersion. (CO2) (Analyzing)(MAY/JUNE 07),(April/May 2010,June 2016)

There is two main causes of intra modal dispersion. They are: i.Material dispersion –Which arises from the variation of the refractive index to the core material as a function of wavelength. ii.Wave guide dispersion – Which occurs because a single mode fiber confines only about 80 percent of the optical power to the core.

14. Define fiber loss. (CO2) (Remembering) (MAY/JUNE 07), (Nov/Dec 2010)

Signal attenuation is otherwise called as fiber loss. It is one which determines the maximum transmission distance between a transmitter and a receiver. The basic attenuation in fiber are absorption, scattering and radioactive losses.

15. What is intermodal dispersion? What is it cause? (CO2) (Remembering) (APR/MAY 08), (Nov/Dec 2010)

The intermodal distortion arises due to the variation in the group delay for each individual mode at a single frequency. When the group velocity of different mode varies, the group delay will be formed.

16. Distinguish intrinsic and extrinsic absorption. (CO2) (Analayzing)(APR/MAY 08)

Intrinsic absorption: Intrinsic absorption occurs when material is in absolutely pure state with no density variation, impurities and material in homogeneities. Thus intrinsic absorption set the fundamental lower limit on absorption for any particular material. **Extrinsicabsorption:** Absorption due to impurities in the fiber material i.e, transition metal impurities and OH ions. The transition metal ions produce losses from 1 to 10 dB/km.

17. What is Intra Modal Dispersion? (CO2) (Remembering)

Intra Modal dispersion is pulse spreading that occurs within a single mode. The spreading arises from finite spectral emission width of an optical source. This phenomenon is also called as group velocity dispersion.

18. What is material dispersion? (CO2) (Remembering) (Nov 2012)

Material dispersion arises from the variation of the refractive index of the core material as a function of wavelength. Material dispersion is also referred to as chromatic dispersion. This causes a wavelength dependence of group velocity of given mode. So it occurs because the index of refraction varies as a function of optical wavelength. Material dispersion is an intra modal dispersion effect and is for particular importance for single ode wave-guide.

19. What is waveguide dispersion? (CO2) (Remembering)

Wave guide dispersion which occurs because of a single mode fiber confines only about 80% of optical power to the core. Dispersion this arises since 20% of light propagates in cladding travels faster than the light confined to the core. Amount of wave-guide dispersion depends on fiber design. Other factor for pulse spreading is inter modal delay.

20. What is group velocity? (CO2) (Understanding)(June 2018)

If L is the distance traveled by the pulse, b is the propagation constant along axis then the group velocity in the velocity at which energy is a pulse travels along the fiber. Vg = C.(db/ k)

21. What is polarization? (CO2) (Understanding)

It is a fundamental property of an optical signal .It refers to the electric field orientation of a light signal which can vary significantly along the length of a fiber.

22. What is pulse Broadening? (CO2) (Remembering)

Dispersion induced signal distortion is that a light pulse will broaden as it travels along the fiber. This pulse broadening causes a pulse to overlap with neighboring pulses. After a time't', the adjacent pulses can no longer be individually distinguished at the receiver and error will occur.

23. What is Profile Dispersion? (CO2) (Remembering)

A fiber with a given index profile (alpha) will exhibit different pulse spreading according to the source wavelength used. This is called as Profile Dispersion.

24. What is M-C fiber? (CO2) (Understanding)

Fibers that have a uniform refractive index throughout the cladding is called as M-C fiber or Matched-cladding fiber.

25. What is D-C fiber? (CO2) (Understanding)

In depressed cladding fiber the cladding portion next to the core has a lower index than the outer cladding region.

26. What is effective cut-off wavelength? (CO2) (Remembering)

It is defined as the largest wavelength at which the higher order LP11 mode power relative to the fundamental LP01 mode power is reduced to 0.1db.

27. Write a note on scattering losses. (CO2) (Understanding) (Nov/Dec 2010)

Scattering losses in glass arise from microscopic variation in the material density from compositional fluctuation and from structural in homogeneities or defects occurring during fiber manufacture.

28. What is Rayleigh scattering? (CO2) (Remembering)

The index variation causes a Rayleigh type of scattering of light. Rayleigh scattering in glass in the same phenomenon that scatters light from sun in the atmosphere, giving rise to blue sky. The expression for Rayleigh scattering loss is given by $\alpha_{scat}=(8\pi^3/3\lambda^2)(n^2-1)2k_BT_f\beta_T$

n = refractive index k_B= boltzman constant β_T= isothermal compressibility

T_f =fictive temperature λ =operative wavelength

29. What is intramodal delay? (CO2) (Remembering)

The other factor giving rise to pulse spreading is intramodal delay which is a result of each mode having a different value of Group velocity at a single frequency.

30. What is the measure of information capacity in optical wave guide? (CO2) (Understanding)

It is usually specified by bandwidth distance product in MHz. For a step index fiber the various distortion effects tend to limit the bandwidth distance product to 20MHz.

31. What are the losses or signal attenuation mechanism occurs in optical fibers. (DEC 2015)(CO2) (Remembering)

Absorption losses, Scattering losses and bending losses

32. Define microscopic bending? (CO2) (Remembering)

Fiber losses occur due to small bending arise while the fiber is inserted into a cable.

33. Define macroscopic bending? (CO2) (Remembering)

If any bending present in the fiber while cabling, the optical power get radiated.

34. The optical power launched into the fiber is 200µw. The transmission distance is 20 km. The optical power at the output of the fiber is 50 µw. Calculate the signal attenuation Per unit length and overall signal attenuation. (CO2) (Applying)(April/May 2010)

Signal attenuation Per unit length = $\frac{10}{L} \log \frac{P_i}{P_0} = \frac{10}{20} \log \frac{200 \text{ X } 10^{-6}}{50 \text{ X } 10^{-6}}$ == 0.3 dB/km

Overall signal attenuation = Attenuation / km X 20 km = 0.3 X 20 = 6 dB.

35. What are the types of non – linear scattering losses? (CO2) (Remembering)

i. Brillouin scattering ii. Raman scattering

36. What are atomic defects? (CO2) (Remembering)

Atomic defects are imperfection of the atomic structure of the fiber material such as missing molecules, high – density clusters of atom groups , or oxygen defects in the glass structure.

37. Mention the way to reduce macro bending losses? (CO2) (Understanding)

1.Designing fibers with large relative refractive index difference and 2. Operating at the shortest wavelength possible.

38. What is linear scattering? (CO2) (Remembering)

Linear scattering transfers linearly the optical power in one propagation mode to different mode. This will occurs in the leaky mode or radiation mode. All linear processes there are no change of frequency on scattering.

39. What do you mean by nonlinear scattering? (CO2) (Remembering)

Nonlinear scattering causes the optical power from one mode to be transferred in either the forward or backward direction to the same, or other modes, at a different frequency. It depends critically upon the optical power density within the fiber and hence only becomes significant above threshold power levels.

40. What is need of GVD? (CO2) (Remembering)

Group Velocity Dispersion parameter determines how much a light pulse broadens as it travels along an optical fiber.

41. What is matched cladding? (CO2) (Remembering)

Matched cladding 1300nm optimized fiber has a uniform refractive index throughout the cladding.

42. What are micro bends? How they are formed? (CO2) (Understanding)(Nov/Dec 09)

Micro bends are repetitive small scale fluctuations in the radius of curvature of the fiber axis. They are formed either by non-uniformities in the manufacturing of the fiber or by non-uniform lateral pressures created during cabling of fibers.

43. What is coupling efficiency? (CO2) (Remembering) (Nov/Dec 2010)

A measure of the amount of optical power emitted from a source that can be coupled into a fiber is given by coupling efficiency .$\eta = P_F/P_S$

44. A Graded index fiber has a core with 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 wavelength of 1μm. (CO2) (Applying)(Nov 2012)

$V = (2\pi aNA/\lambda) = ((2 \text{ X } 3.14 \text{ X } 25 \text{ X } 10^{-6} \text{X } 0.2) / 1\text{X}10^{-6})) = 31.4$

$M = V^2/4 = (31.4^2/4) = 247$

45. What is attenuation? (CO2) (Remembering) (Dec/Jan 2017)

Attenuation is the measure of decay of signal stength or loss of light power that occurs as light pulse propagate through the length of the fiber.

46. Compare axial, longitudinal and angular misalignment. (CO2) (Evaluating)

<u>Axial misalignment</u> : Lateral or axial misalignment occurs when the axes of two fibers are separated by distance d. **<u>Longitudinal misalignment</u> :**Longitudinal misalignment occurs when the fibers have the same axis but have a gap 's' between their end faces. **<u>Angular misalignment</u>**: Angular misalignment occurs when two fiber axes from an angle 'θ' between fiber end faces.

47. What are the factors of splicing? (CO2) (Understanding)

The factors to be considered in splicing are i. Geometrical difference between two fibers ii. Fiber misalignments at the joint and iii. Mechanical strength of the splice

48. What are the techniques used in splicing? (CO2) (Understanding)

Three splicing techniques are used i. Fusion splice ii. V – groove mechanical splice iii. Elastic tube splice

49. Compare splice and connector. (CO2) (Analyzing)

Splice is a permanent joint and the bonding formed is permanent. Connector is a temporary joint or demountable joint. Splice loss is very small when it is compared with connector loss.

50. What are splices? What are the requirements of splices? (CO2) (Understanding)

The splices are generally permanent fiber joints, whereas connectors are temporary fiber joints. Splicing is a sort of soldering. The requirements of splices are: i. Should cause low attenuation ii. Should be strong & light in weight iii. Should have minimum power loss iv.Should be easy to install

51. What are connectors? What are the types of connectors? (CO2) (Understanding)

The connectors are used to join the optical sources as well as detectors to the optical fiber temporarily. They are also used to join two optical fibers. The two major types of connectors are :i.Lensed type expanded beam connector ii. Ferrule type connector.

52. What are the requirements of a good connector? (CO2) (Understanding)

The requirements of a good connector are as follows: i.Low loss ii. Repeatability iii. Predictability iv. Ease of assembly and use v. Low cost & reliability vi. Compatibility

53. What are the techniques used for end – preparation? (CO2) (Understanding)

Saving, grinding and polishing, and controlled – fracture techniques are used for end-preparation.

54. List the different types of mechanical misalignments that can occur between two jointed fibers. (CO2) (Understanding) (Nov/Dec 07)

i.Lateral (axial) misalignment ii.Longitudinal misalignment iii.Angular misalignment

55. Define the attenuation coefficient of fiber. (CO2) (Remebering)(Nov/Dec 2011)

The standard formula for expressing the total power loss in an optical fiber cable is

α_{dB} = 10 log (P_i/P_0) where α_{dB} is total reduction in power level(attenuation) in decibels, P_0 -cable output power(Watts) P_i- cable input power (Watts)

56. Calculate the cut off wavelength of an optical signal to the fiber with its core refractive index of 1.50 and that of cladding 1.46. The core radius of 25μm.The normalised frequency is 2.405. (CO2) (Applying)(Nov/Dec 2011)

Cut off wavelength $\lambda_c = (2\pi a n_1(2\Delta)^{1/2}/V$, $\Delta=(n_1-n_2)/n_1=(1.50-1.46)/1.50 = .0267$

For single mode, normalised frequency V_c=2.405

$\lambda_c = [2X3.14X1.50X25X(2X.0267)^{1/2}] / 2.405 = 26\mu m$

57. What are the two reasons for chromatic dispersion? (CO2) (Analyzing)(Nov/Dec 2012)

i)This dispersion arises due to the variation of the refractive index of the core material as a function of wavelength or frequency of light. ii) this causes a wavelength dependence of the group velocity of any given mode. i.e pulse spreding occurs even different wavelengths follow the same path.

58. What are the most important non-linear effects of optical fiber communication? (CO2) (Understanding) (Nov/Dec 2012)

This nonlinear scattering causes the optical power from one mode to be transferred in either the forward direction to the same, or other modes at a different frequency.

59. Interpret bandwidth distance product.(CO2)(Understanding)(APR/MAY2019)

The information –carrying capacity of any electronic communication system is directly proportional to bandwidth. The product of bandwidth and distance is bandwidth distance product. Optical fiber cables have, for all practical purposes, an infinite bandwidth.

<u>16 MARKS</u>

1. i).What is meant by wave guide dispersion? Derive the expression for the same.(CO2)(Understanding)(Nov/Dec 2013) (Dec 2015)
ii).What is meant by material dispersion? Derive the expression for the pulse broadening due to material dispersion. (Understanding)((NOV/DEC 04,June 2016) (or) Discuss in detail about intra-modal dispersion with relevant expression and diagrams. (CO2) (Nov/Dec 10)(Dec 2015)

2. Discuss pulse broadening in graded index fibers.(CO2) (Creating)(APR/MAY 05)& (Nov/Dec 09),(Nov/Dec 2013), (Nov/Dec 2011)

3. i. Sketch the fundamental mode field in a curved optical wave guide and explain how bending losses occur? (Understanding) ii. Find the radius of curvature at which the number of modes (in a bent fiber) decreases by 50% in a graded index fiber. $\alpha = 2$, $n_2 = 1.5$, $\Delta = 0.01$, a = 25μm and λ = 1.3μm. (CO2) (Applying)

4. Discuss the design optimization of single mode fibers. (CO2) (Creating) (NOV/DEC 06, Nov 2012, Nov/Dec 2014 Apr/May 2010)

5. When the mean optical power launched into an 8 km length of fiber is 120 μW, the mean optical power at the fiber output is 3 μW. Determine (i) Over signal attenuation in dB/km. ii) The overall signal attenuation for a 10 km optical link using the same fiber with splices at 1km intervals, each giving an attenuation of 1dB. (CO2) (Analyzing)(NOV/DEC 07,Apr/May2019)

6. Explain with suitable diagrams the different mechanism that contributes to attenuation in optical fibers. (CO2) (Evaluating)(NOV/DEC 07),(Nov/Dec 2010),(Nov/Dec 2013, June 2018)

7. Discuss in detail intermodal and intramodal dispersion with relevant expression and diagrams. (CO2) (Creating) (NOV/DEC 07, June 2018)

8. Explain the scattering and bending losses that occur in an optical fiber with relevant diagrams and modes expressions. (CO2)(NOV/DEC 08, Nov 2012),(Nov/Dec 2013, Nov/Dec 2014) (Dec 2015)

9. Discuss polarization mode dispersion and its limitations. (CO2) (Understanding)((NOV/DEC 08,Apr/May2019)

10. i. Explain the effects of signal distortion in optical waveguide. (Understanding) ii. Compute the total intermodal, intramodal and total dispersion for a fiber having fiber length 1 km, line width 50nm, intermodal and intramodal dispersion 5 ns/km and 80 ps/km respectively. (CO2) (Applying)

11. Discuss the various kinds of losses that an optical signal might suffer which propagating through fiber. Which is most important one? What if the effect of these losses on light power and pulse shape? (CO2) (Analyzing) (MAY/JUNE 07)
12. A 6 km optical link consists of multimode step index fiber with a core refractive index of 1.5 and a relative refractive index difference of 1%.Estimate the delay difference between the slowest and fastest modes at the fiber output and the rms pulse broadening due to intermodal dispersion on the link. Also derive the expression involved in it. (CO2) (Applying) (APR/MAY 08, Nov 2012)
13. Describe the linear and non linear scattering losses in optical fiber. (CO2) (Understanding)(Nov/Dec 09)
14. Silica has an estimated fictive temperature of 1400 K with an isothermal compressibility of 7 X 10^{-11} m^2N^{-1}.The refractive index and the photo elastic coefficient for silica are 1.46 and 0.286 respectively. Determine the theoretical attenuation in dB/km due to the fundamentals Rayleigh scattering in silica at optical wavelengths 850 nm,1310nm and 1550nm. (CO2) (Evaluating)(Nov/Dec 09,Apr/May 2019)
15. i.What is meant by fiber splicing. Explain fusion splicing of optical fiber. ii.Explain expanded beam fiber connector with neat schematic. (CO2) (Understanding)(Nov/Dec 2011) (Dec 2015,Apr/May 2019)
16. Explain the different lensing schemes available to improve the power coupling efficiency. (CO2) (Understanding)(Nov2012),(Nov/Dec 2013, June 2018)
    ii. Explain the fiber splicing techniques with necessary diagrams. (CO2)(Understanding) (Nov/Dec 07), (Nov/Dec 10) (Dec 2015)
17. Explain the mechanical misalignments that can occur between two joined fibers with necessary diagrams. (CO2) (Understanding)((Nov/Dec 08, Nov 2012)
18. Describe the three types of fiber misalignment that contribute to insertion loss at an optical fiber joint. (CO2) (Understanding)(Nov/Dec 2014)
19. (i) What do you mean by pulse broadening? Explain its effect on information carrying capacity of a fiber. (Understanding) (ii) An LED operating at 850 nm has a spectral width of 45 nm.What is the pulse spreading in ns/km due to material dispersion? What is the pulse spreading when a laser diode having a 2 nm spectral width is used? The material dispersion is 90 ps/nm km. (CO2) (Applying) (Nov/Dec 2011)
20. (i)What is meant by ‘fiber splicing’? Explain fusion splicing of optical fibers.(ii) Explain expanded beam fiber connector with a neat diagram. (CO2) (Understanding) (Nov/Dec 2011) (Dec 2015)
21. (i) Describe the linear and non-linear scattering losses in optical fibers.(ii) An LED operating at 850nm has a spectral width of 45mm. What is the pulse spreading in ns/km due to material dispersion? What is the pulse spreading when a laser diode having a 2nm spectral width is used? (CO2) (Analyzing) (Nov/Dec 2012)
22. (i) Draw and explain the various fiber alignment and joint losses.(ii) Write notes on fiber splices and connectors . (CO2) (Understanding) (Nov/Dec 2012, June 2018)
23. A multi mode graded index fiber exhibits total pulse broadening of 0.1μs over a distance of 15 km. Estimate the maximum possible bandwidth on the link assuming no inter symbol interference, pulse dispersion/ unit length, bandwidth length product for the fiber. (CO2) (Applying) (May 2010)
24. Outline the major categories of multiport fiber optic coupler. (CO2) (Understanding)(Nov/Dec 2014)
25. Discuss dispersion mechanisms with regard to single – mode fibers indicating the dominating effects. Hence, describe how intramodal dispersion may be minimized within the single – mode region.(June 2016) (CO1)(Analyzing)

UNIT III-OPTICAL SOURCES

TWO MARKS

1. **Define radiance. (CO3)(Remembering) (Nov/Dec 04)**

   It is measure of optical power radiated into a unit solid angle per unit area of the emitting surface. The unit of radiance or power is Watts. High radiances are required to couple sufficiently high optical power levels into a fiber.
2. **What is meant by population inversion? (CO3) (Remembering) (Nov/Dec 04,Nov 2012)**

   Stimulated emission will exceed absorption only if the population of the excited states is greater than that of the ground state. This condition is called as population inversion.
3. **What is meant by indirect band gap semi conductor material? (CO3) (Remembering) (Apr/May 05, June 2018)**

For indirect band gap materials, the conduction – band minimum and valance –band maximum energy level occurs at different values of momentum. In indirect band gap materials direct transition is not possible from valence band to conduction. To perform band to band recombination, it must involve third particle phonons to conserve momentum. e.g.Si, Ge

4. **What is meant by hetero junction? Mention its advantages. (CO3) (Understanding) (Apr/May 05), (Nov 2012), (Nov/Dec2007)**

A heterojunction consists of two adjoining semiconductor materials with different band gap energies. They have adequate output power and efficiency, out power can be directly modulated and they are dimensionally compatible with the optical fiber.

5. **Mention the three key transition processes involved in laser action. (CO3) (Remembering) (Nov/Dec 05),(Apr/May 2010)**

Three key processes i. photon absorption ii. Spontaneous emission iii. Stimulated emission

6. **Give the example for direct and indirect semiconductor materials. (CO3) (Understanding)(May/June 06)**

In direct band gap materials direct transition is possible from valence band to conduction band. e.g.GaAs, InP, InGaAs. In indirect band gap materials direct transition is not possible fromvalence band to conduction. e.g.Silicon, Germanium.

7. **Define internal quantum efficiency of an LED. (CO3)(Remembering) (Nov/Dec 06) (Nov/Dce 2014)**

The internal quantum efficiency in the active region is the fraction of the electron – hole pairs that recombine radiatively. The internal quantum efficiency is defined as the ration of radiative recombination rate to the total recombination rate. $\eta_{int} = \underline{Rr/}R_r + R_{nr}$

R_r – Radiative recombination rate, R_{nr} – non radiative recombination rate

8. **Distinguish direct and indirect band gap materials. (CO3) (Analyzing)(Nov/Dec 08) (Nov/Dec 09)(Dec 2015)**

direct band gap	**indirect band gap**
i.Direct recombination id possible	To perform recombination it must involve a third particle.
ii.Electron and hole have the same momentum value	Different values of momentum
iii.Life time of charge carriers is less	Life time of charge carriers is more
iv.Used in fabricate LED & LASER	Used in fabricate transistor and diode

9. **An LED has radiative and non radiative recombination times of 30 and 100ns respectively. Determine the internal quantum efficiency. (CO3) (Applying)(Nov/Dec 08)**

Given :$\tau_r = 30$ ns $\tau_{nr} = 100$ns

Internal quantum efficiency $\eta_{int} = \tau/\tau_r$

$$\text{Bulk recombination life time } \tau = \frac{\tau_r \tau_{nr}}{\tau_r + \tau_{nr}} = \frac{30 \times 100}{30 + 100} = 23.1 \text{ ns}$$

$$\eta_{int} = 23.1/30 = 0.77$$

10. **When a LED has 2 V applied to its terminals, it draws 100 mA and produces 2 mW of optical power. Determine the LED conversion efficiency from electrical to optical power. (CO3) (Applying)(May/June 09)**

Electric power = 2 X 100 nA = 200 mW

conversion efficiency = optical power / electrical power = (2mW / 200 mW)X 100 = 1 %

11. **What is the principle of operation of LASER? (CO3) (Understanding)(May/June 09)**

When a photon having energy equal to the energy difference between the two states (E2 –E1) interacts with the atom in the upper energy state causing it to return to the lower statewith the creation of a second photon, light emission occurs by this stimulated emission.

12. **Compare LED and LASER. (CO3) (Evaluating)(May/June 07,June 2016, June 2018,May 2019)**

LED	**LASER**
i. The output obtained is incoherent ii. LEDs are coupled into multimode fiber only. iii. Less expensive and less complex iv. Long lifetime.	i.The output obtained is coherent ii.Single mode or multimode fiber. iii. More expensive and more complex iv. Less lifetime.

13. **Compare LED source and ILD source. (CO3) (Evaluating)(Apr/May 08, Nov/Dec 2014)**

LED	**ILD**

i. LED emit incoherent light ii. Radiant output power less iii. LED can not use a higher bit rates.	i.ILD emit coherent light ii. Radiant output power more than LED iii. Used a higher bit rates.

14. What are the advantages of LED? (CO3) (Understanding)(Nov / Dec 2013)

LEDs are less complex circuits than Laser diodes 2.Fabrication is easier 3.They have long life.

15. What are the two types of confinement used in LEDs? (June 2016) (CO3) (Remembering)

i. optical confinement. ii. Carrier confinement.

16. What are the two types of LED configurations? (CO3) (Remembering)

i. homo junction ii. Single and double hetero junction.

17. What are the three requirements of Laser action? (CO3) (Remembering)

i. Absorption ii. Spontaneous emission iii.stimulated emission.

18. What are the three types of Laser diode structures? (CO3) (Remembering)

i. Gain indexed guide ii. Positive indexed guide iii. Negative indexed guide

19. What are the fundamental structures of Index guided lasers? (CO3) (Remembering)

i. buried hetero structure. ii. Selectively diffused construction iii. Varying thickness structure iv. Bent layer configuration.

20. What are the three basic methods of current confinement? (CO3) (Understanding)

i. Preferential dopant diffusion. ii. Proton implantation iii. Inner strip confinement iv. Re growth of back biased PN junction.

21. Define modulation. (CO3) (Remembering)

The process of imposing information on a light stream is called modulation. This can be achieved by varying the laser drive current.

22. Define external quantum efficiency. (CO3) (Remembering)

The external quantum efficiency is defined as the number of photons emitted per radiative electron-hole pair recombination above threshold.

23. Define threshold current. (CO3) (Remembering)

The threshold current is conventionally defined by extrapolation of the lasing region of the power-versus-current curve. At high power outputs, the slope of the curve decreases because of junction heating.

24. Define longitudinal modes. (CO3) (Remembering)

Longitudinal modes are associated with the length of the cavity and determine the typical spectrum of the emitted radiation.

25. Define lateral modes. (CO3) (Remembering)

These modes lie in the plane of the pn junction. They depend on the sidewall preparation and the width of the cavity. It determines the shape of the lateral profile of the laser beam.

26. Define transverse modes. (CO3) (Remembering)

Transverse modes are associated with the electromagnetic field and beam profile in the direction perpendicular to the plane of the pn junction. They determine the laser characteristics as the radiation pattern and the threshold current density.

27. Mention any four factors which affect the power launched into the fiber. (CO3) (Understanding)

i. Core radius of the fiber ii. Radiation pattern of the source iii. Alignment between source and fiber iv. Numerical aperture of the fiber.

28. Define the three modes of the cavity of laser. (CO3) (Remembering) (Nov/Dec 09)

i.Longitudinal modes : Longitudinal modes are related to the length L of the cavity.
ii. Lateral modes : Lateral modes lie in the plane of the PN junction. These modes depend upon the side wall preparation and width of the cavity. iii. Transverse modes: Transverse modes are associated with the Electromagnetic field and beam profile in the direction perpendicular to the plane of the PN junction. These modes determine the radiation pattern of the laser.

29. What is a DFB laser? What is its main difference from the other lasers? (CO3) (Analyzing) (Nov/Dec 09)

In DFB laser the lasing action is obtained by periodic variations of refractive index, which are incorporated into multilayer structure along the length of the diode. DFB laser does not require optical feedback unlike the other lasers.

30. A double heterojunction InGaAsP LED emitting at a peak wavelength of 1310 nm has radiative and nonradiative recombination times of 30 and 100ns respectively. The drive current is 40mA. Find the bulk recombination lifetime and internal quantum efficiency. (CO3) (Applying)(Nov 2012)

$\tau = (\tau_r\tau_{nr}/(\tau_r+\tau_{nr}))$ = (30ns X 100ns/(30ns+ 100ns)) = 23.1ns

$\eta = \tau/\tau_r$ = 23.1ns/30ns = 77%

31. Compare and contrast between surface and edge emitting LEDs. (CO3) (Analyzing) (Nov/Dec 2012,MAY2019)

i)In surface emitting LEDs, the plane of active light emitting region is perpendicular to the fiber axis. ii) Edge emitting LEDs emit a more directional pattern than the surface emitting LEDs. Iii) In order to reduce the losses caused by absorption in the active layer and to make the beam more directional, the light is collected from the edge of the LED. Such a device is known as Edge emitting LED. iv) Edge emitter have a substantially better modulation bandwidth of the order of hundreds of megahertz than comparable surface emitting structure with the same drive level. V) The coupling losses with surface emitters are greater and they have narrow bandwidths. Vi) Edge emitter couple 7.5 times more power into low NA fiber than a comparable surface emitter.

32. What are the characteristics of semiconductor laser diode should posses?(CO3) (Understanding)(Nov/Dec 2011)

For optical fiber system, semiconductor laser diodes are used as an optical source because its output radiation is highly monochromatic and the light beam is very directional.

33. Give the expression for total optical power emitted from an LED. (CO3) (Remembering) (Nov/Dec 2010)

P = $\eta_{ext} P_{int} = P_{int} / n (n+1)^2$ where $\eta_{ext}= 1/ n (n+1)^2$

34. Why silicon is not used to fabricate LED or Laser diode? (CO3) (Analyzing)(Nov/Dec 2011)

The spontaneous and stimulated emission processes are vastly more efficient in direct band gap semiconductors than in indirect band gap semiconductors, therefore silicon is not a common material for laser diodes.

<u>16 MARKS</u>

1. Draw the two basic LED Configurations and discuss the Principle. Derive the internal quantum efficiency of an LED. (CO3) (Understanding)(Nov/Dec 04), (may2010),(Nov/Dec 10), (Nov/Dec 2013) (Dec 2015, June 2018)

2. i. Discuss the principle of optical feedback and LASER oscillation. (CO3) (Creating)(Nov/Dec 04)(Nov/Dec 2014)

ii. Derive the threshold condition for LASER oscillation. (CO3) (Understanding)

3. Discuss the laser diode structures and radiation pattern. (CO3) (Creating) (Apr/May 05)

4. Discuss the LASER diode principle, modes and threshold condition. (CO3) (Understanding) (Nov/Dec 05),(Nov/Dec 13) (Dec 2015)

5. What is meant by heterojunction? Give example. (CO3) (Remembering)(May/June 06)

6. Explain optical feedback and laser oscillation. (CO3) (Understanding)(May/June 06)

7. Draw the double – heterostructure light emitter and explain. (CO3) (Understanding)(Nov/Dec 06,Apr/May 2019)

8. Explain laser action with neat diagrams. (CO3) (Understanding) (Nov/Dec 06)

9. A GaAs laser operating at 850 nm has a 500μm length and a refractive index n = 3.7. What are the frequency and wavelength spacings? (CO3) (Applying)(Nov/Dec 06)

10. i.Draw and explain the LED structures based Double Hetero structure configuration. ii. Discuss the principle of operation of laser diodes. What are the effects of temperature on the performance of a laser diode? (CO3) (Understanding) (Nov/Dec 07), (Nov/Dec 2013)

11. i. Draw and explain the different structures used to achieve carrier and optical confinement in laser diodes. ii. Discuss the effects of temperature on the performance of a laser diode. iii. Give a brief account of modulation of an LED. (CO3) (Understanding) (Nov/Dec 08)

12. i. Derive expressions for the power coupled from a surface emitting LED into step index and graded index fibers. (CO3) (Understanding) (Nov/Dec 08, May 2010,Nov 2012)

13. Discuss about modulation of laser diodes. Why thermoelectric cooler are used in laser diodes? (CO3) (Creating)(Nov 2012) (Dec 2015)

14. Derive an expression for the internal optical power level generated in LEDs. (CO3) (Analayzing)(Apr/May 08)

15. Discuss the laser diode structures and radiation pattern. (CO3) (Creating)

16. Explain direct and indirect band gap material. (CO3) (Understanding)

17. Explain the theory of stimulated emission and lasing with the help of Energy band diagrams. Also explain its temperature dependence characteristics. (CO3) (Understanding) (Nov/Dec 09)

18. Compare the threshold current densities at 32^0C and 100^0C for a AlGaAs injection Laser with T_0 = 160 K and the similar ratio for an InGaAlP device with T_0 = 55K. (CO3) (Applying)(Nov/Dec 09)

19. (i) Compare LED with a laser diode. (CO3) (Evaluating)(ii) With the help of a neat diagram explain the construction and working of a surface emitting LED. (Understanding) (Nov/Dec 2011)

20. (i)Draw and explain the LED structures based Double Hetero structure configuration.(ii) Discuss the principle of operation of Laser diodes. What are the effects of temperature on the performance of a laser diode? (Understanding) (CO3) (Nov/Dec 2007)

21. Explain the different lensing schemes available to improve the power coupling efficiency (CO3) (Understanding) (May 2010),(Nov/Dec 2007) (Dec 2015)

22. (i)Draw and explain the different structures used to achieve carrier and optical confinement in laser diodes. (ii) Discuss the effects of temperature on the performance of a laser diode.(iii) Give a brief account of the modulation of an LED. (CO3) (Understanding) (Nov/Dec 2009, June 2018)

23. Derive expressions for the power coupled from a surface emitting LED into step index and graded index fibers. (ii) Explain the mechanical misalignments that can occur between joined fibers with necessary diagrams. (CO3) (Understanding) (Nov/Dec 2009)

24. The refractive index of the InGaAsP active region of an injection laser at a wavelength of 1.5µm is 3.5 and the active has an active cavity length of 400µm.For laser operation at a wavelength of 1.5µm determine: i) the laser emission mode index ii) the eligible number of wavelength inside the cavity iii)the frequency separation of the modes in active cavity in order to produce constructive interference.(CO2)(Applying)(June 2016)

25. A GaAs LED is forward- biased with a current of 120 mA and a voltage of 1.5 V.Each emitted photon possesses an energy of 1.43 eV, and the refractive index of GaAs is 3.7. The configuration of the LED is such that we may neglect back emission and self absorption within the semiconductor. Assuming the internal quantum efficiency of the LED to be 60%, Calculate i)The internal power efficiency of the device and ii)the external power efficiency of the device.

UNIT – IV OPTICAL RECEIVER

1. Define responsivity. (CO4) (Remembering) (Nov/Dec 04),(Nov/Dec 2009),(Nov/Dec 2012),(Nov/Dec 2013)

The responsivity is a useful parameter as it gives the transfer characteristic of the detector. It is defined as the ratio of output photocurrent to the incident optical power. $R = I_p / P_0$ (AW^{-1})

2. Define long wavelength cut off related to photo diode. (CO4) (Remembering) (Nov/Dec 04)

Long wavelength cut off is determined by band gap energy E_g of material. $\lambda_c(\mu m) = \frac{hC}{E_g} = \frac{1.24}{E_g(eV)}$

Typical value of λ_c for silicon is 1.06 µm and for germanium it is 1.6 µm.

3. A given APD has a quantum efficiency of 75% at a wavelength of 800 nm. If 0.5 µW of optical power produces a multiplied photocurrent of 12µA, find the multiplication M. (CO4) (Applying)

Given : I_M = 12 µA, λ = 800 nm = 8×10^{-7}m , P_0 = 0.5 µW = 5×10^{-7}W

Multiplication factor (M) = I_M / I_P

Primary photocurrent $I_P = RP_0 = \frac{\eta q P_0}{h\upsilon} = \frac{\eta q \lambda P_0}{hC}$

I_P = 0.2415 µA

M = 12µA / 0.2415 µA = 49.5

4. Define quantum efficiency of a photo detector. (CO4) (Remembering) (Apr/May10),(Nov/Dec2011), (Nov/Dec 2013)

It is defined as the number of the electron – hole pairs generated per incident photon of energy hυ and is given by $\eta = \frac{\text{No.of electron-hole pairs generated}}{\text{No. of incident photons}} = \frac{(I_p/q)}{P_0/h\upsilon}$

5. Compare the performance of APD and PIN diode. (CO4) (Evaluating)(Nov / Dec 08), (Nov/Dec 2009)

PIN	APD
i. No internal gain ii. Less sensitive iii. Low reverse biasing iv. Simple circuit v. Low cost	i. Internal gain ii. More sensitive iii. High reverse biasing iv. Complex circuit v. More expensive

6. **A silicon APD has a quantum efficiency of 65% at a wavelength of 900 nm. If 0.5 μW of optical power produces a multiplied photocurrent of 10μA, find the multiplication M. (CO4) (Applying)**

Given: $I_M = 10\ \mu A$, $\lambda = 900\ nm = 9X\ 10^{-7}m$, $P_0 = 0.5\ \mu W = 5 \times 10^{-7}W$

Multiplication factor (M) = I_M / I_P

Primary photocurrent $I_P = RP_0 = \frac{\eta q P_0}{h\upsilon} = \frac{\eta q \lambda P_0}{hC}$

$$I_P = \frac{0.65 \times 0.6 \times 10^{-6} \times 1.602 \times 10^{-19} \times 900X10^{-9}}{6.626 \times 10^{-34} \times 3 \times 10^8} = 0.236 \times 10^{-6}\ A$$

$M = 10\mu A / 0.236\mu A = 42.37$

7. **What is meant by impact ionization in APD? (CO4) (Understanding)(Dec 2015)**

In order for carrier multiplication to take place, the photo generated carriers must traverse a region where a very high electric field is present. In this high field region, a photo generated electron or hole can gain energy so that it ionizes bound electrons in the valence band upon colliding with them. This carrier multiplication mechanism is known as impact ionization.

8. **Define avalanche effect. (CO4) (Remembering) (NOV-2011)**

The newly created carriers are accelerated by the high electric field, thus gaining enough energy to cause further impact ionization. This phenomenon is called avalanche effect.

9. **Define ionization rate. (CO4) (Remembering)**

The avg. no. of electron hole pairs created by a carrier per unit distance traveled is called ionization rate.

10. **What are the advantages of photodiodes? (CO4) (Remembering) (May 2010),(NOV-2011)**

i. Small size ii. Suitable material iii. High sensitivity iv. Fast response time

11. **Define photocurrent**. **(CO4) (Remembering)**

The high electric field presents in the depletion region causes the carriers to separate and be collected across the reverse-biased junction. This gives to a current flow in the external circuit, with one electron flowing for every carrier pair generated. This current flow is known as photocurrent.

12. **What are the conditions to be met for a high signal- to- noise ratio in a photo detector? (CO4) (Understanding)**

i. The photo detector must have a high quantum efficiency to generate a large signal power

ii. The p and amplifier noises should be kept as low as possible.

13. **Define minimum detectable optical power. (CO4) (Remembering)**

It is defined as the optical power necessary to produce a photocurrent of the same magnitude as the root mean square of the total current.

14. **Define quantum noise**. **(CO4) (Remembering)**

It is not possible to predict exactly how many electron-hole pairs are generated by a known optical power incident on the detector is the origin of the type of short noise called quantum noise.

15. **Give the advantages of Pin photodiodes. (CO4) (Understanding)(Nov 2012)**

i.Very low reverse bias is necessary ii. High quantum efficiency iii. Large bandwidth iv. Low noise level

16. **What do you mean by thermal noise? (CO4) (Understanding)**

Thermal noise is due to the random motion of electrons in a conductor. Thermal noise arising from the detector load resistor and from the amplifier electronics tend to dominate in applications with low signal to noise ratio.

17. **Give the equation for mean square shot noise. (CO4) (Understanding)**

The mean square shot noise is given by $\langle in^2 \rangle = 2qI_B$ I_B - average output current B -bandwidth of the amplifier

18. **Define avalanche multiplication M. (CO4) (Remembering)**

The multiplication M for all carriers generated in the photodiode is defined by M = Im/Ip

I_M - average value of the total multiplied output current, I_P -primary un multiplied photocurrent

19. **What is current mode of operation of photodiode? (CO4) (Remembering)**

In photo conducting mode, the photocurrent is slightly dependent on the reverse bias. For a constant reverse bias, the current is linear. This is called current mode of operation of the photodiode.

20. **What are the factors on which response time depends**? **(Or)On what factors the response time of photo detector depends? (CO4) (Analayzing)(Nov/Dec 10,MAY2019)**

i. The transit time of the photo detector carries in the depletion region. ii. The diffusion time of the photo carriers generated outside the depletion region. iii. The RC time constant of the photodiode and its associated circuit.

21. Define photodiode dark current? (CO4) (Remembering)

It is the current that continues to flow through the bias circuit of the device when no light is incident on the photodiode. This is a combination of bulk and surface currents.

22. What is P^+ ΠP n^+ reach- through structure? (CO4) (Remembering)

The reach –through avalanche photodiode (RAPD) is composed of a high resistivity p- type material deposited as an epitaxial layer on a p+ substrate. A p type diffusion is then made in the high resistivity material, followed by the construction of an n+ layer. The configuration is called P^+ ΠP n^+reach- through structure.

23. A photodiode is constructed of GaAs, Which has a band energy of 1.43eV at 300 K. Find long wavelength cutoff. (CO4) (Applying)(May/June 07, Nov 2012)

$$\text{Long wavelength cutoff } \lambda_c = \frac{hc}{Eg} = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{1.43\text{eV} \times 1.6 \times 10^{-19}} = 869 \text{ nm}$$

24. List out the values of operating wavelength and responsivities of Si, Ge and InGaAs photodiodes. (CO4) (Remembering) (Nov/Dec 09)

Si : Operating wavelength = 400-1100nm &Responsivity = 0.4-0.6
Ge : Operating wavelength = 800-1650nm &Responsivity = 0.4-0.5
InGaAs : Operating wavelength = 1100-1700nm & Responsivity = 0.75-0.95

25. What is meant by (1/f)noise corner frequency? (CO4) (Remembering) (Nov/Dec 09)

The (1/f) noise corner frequency fc is defined as the frequency at which 1/f noise, which dominates the FET noise at low frequencies and has 1/f power spectrum becomes equal to the high frequency channel noise given by Γ.

26. What is excess noise factor? (CO4) (Remembering) (Nov/Dec 10)

The ratio of actual noise generated in an avalanche photodiode to the noise that would exist if all carrier pair were multiplied by exactly M is called the excess noise factor F.

$$F = \langle m^2 \rangle / \langle m \rangle^2 = \langle m^2 \rangle / M^2$$

27. What is the significance of intrinsic layer in PIN diodes? (CO4) (Understanding)(Nov/Dec 2012)

The pin photo detector structure consists of p and n regions separated by a very lightly n-doped intrinsic region. When the photodiode is reverse biased, the intrinsic region of diode is fully depleted of carriers

28. What are the drawbcks of avalnche photo diode? (CO4) (Understanding)(Nov/Dec 2014)

Fabrication difficulty due to their more complex structure ii. Cost is high iii. High bias voltage is required iv. Internal gain depends on temperature, thus temperature compensation is necessary to stabilize the device operation.

29. A photon of energy 1.53X10-^{19} joules are incident on a photodiode which has responsivity of 0.75A/W.If the optical power level is 10μW then the find out the photo current generated. (CO4) (Applying)(Nov/Dec 11)

Given : R_0 = 0.5 A/ W Po= 10μW

Primary photocurrent $I_P = RP_0$ = .075A/W X 10 μW =7.5 Ma

30. What is meant by quantum limit? (CO4) (Remembering) (May/June 06), (Nov/Dec 10), (Nov/Dec 11), (May/June 13)(Dec 2015, June 2018,MAY2019)

It is possible to find the minimum received optical power required for a specific bit error rate performance in a digital system. This minimum received power level is known as quantum limit.

31. List the important requirements of an optical receiver. (CO4) (Remembering)

i. High sensitivity at the operating wavelengths. ii. High fidelity iii. Small size iv. Short response time to obtain a suitable bandwidth. v. A minimum noise introduced by the detector.

32. What is meant by inter symbol interference (ISI) ? (CO4) (Remembering)

ISI results from pulse spreading in the optical fiber. The presence of this energy in adjacent time slots results in an interfering signal. Hence it is called ISI.

33. What is meant by bit error rate? (CO4) (Understanding)

To divide the number N_e of errors occurring over a certain time interval t by the number Nt of pulses transmitted during this interval. This is called bit error rate or error rate.

Bit error rate BER = N_e/N_t = Ne/ B_t Where B = 1/ Tb

34. Mention the drawbacks of high impedance amplifier. (CO4) (Understanding)

Drawbacks of high impedance amplifier i. For broadband application, equalization is required ii. It has lime dynamic range.

35. **Define rise time and fall time. (CO4) (Remembering)**

Rise time : The rise time is measured from 10 to 90 percent of the leading edge of the output pulse. Fall time : The fall time is measured from 90 to 10 percent of the falling edge of the output pulse.

36. **What are the benefits of a trans impedance amplifier? (CO4) (Understanding)(May/June 07), (Nov/Dec 10)**

i. It has a wide dynamic range compared with the high impedance amplifier. ii. The output resistance is small so that amplifier is less susceptible to pickup noise, cross talk, electromagnetic interference etc.

37. **What is Dark current . (CO4) (Remembering) (Nov/Dec 2012)**

It is the current that continues to flow through the bias circuit of the device when no light is incident on the photodiode. This is a combination of bulk and surface currents.

38. **List out the various error sources. (CO4) (Remembering) (Nov/Dec 2011),(Nov/Dec 2012), (May/June 2013)**

i. Quantum noise ii. Bulk dark current iii. surface leakage current iv.Thermal noise v. Amplifier noise.

39. **A Digital fiber optic link operating at 1310nm, requires a maximum BER of 10^{-8} .Calculate the required average photons per pulse. (CO4) (Applying)(Nov/Dec 2013)**

$P_r(0) = e^{-\bar{N}} = 10^{-9}$ Solving for $\bar{N}$ = 8 ln10= 18.42

40. **The photo detector output in cutback attenuation is 3.3V at the far end of the fiber. After cutting the fiber at the near end, 5m from the far end, Photo detector output read was 3.92V.What is the attenuation of the fiber in dB/km. (CO4) (Applying)(Nov/Dec 2013)**

α_{dB}=[10/(L_1-L_2)] X $\log_{10}$(V2/V1) =[10/(-5m)] X $\log_{10}$(3.92/3.3)=-2 X 0.07477=.-0149

41. **A 2km length of multimode fiber is attached to apparatus for spectral loss measurement. The measured output voltage from the photo receiver using the full 2km fiber length is 2.1V at a wavelength of 0.85μm.When the fiber is then cut back to leave a 2m length, the output voltage increases to 10.7V.Determine the attenuation per kilometer for the fiber at a wavelength of 0.85 μm and estimate the accuracy of the result(CO4).(Applying)**

α_{dB}=[10/(L_1-L_2)] X $\log_{10}$(V2/V1)= [10/(2km-2m)] X $\log_{10}$(10.7/2.1) = 3.5 dB/km

Uncertainty = ±0.2/(L_1-L_2) =± 0.2/(2km-2m) = ± 0.1Db

42. **Define threshold level. (CO4) (Remembering) (Nov/Dec 2011)**

A decision circuit compares the signal in each time slot with a certain reference voltage known as threshold level

i. Received signal > Threshold = 1 ii. Received signal < Threshold = 0

43. **An He-Ne laser operating at a wavelength of 0.63μm was used with a solar cell cube to measure the scattering loss in multimode fiber sample. With a constant optical output power the reading from the solar cell cube was 6.14nV. The length of the fiber in the cube was 2.92cm. Determine the loss due to scattering in dB/km for the fiber at a wavelength of 0.63μm. (CO4) (Applying)**

αsc= [(4.343 X10^5)/L(cm)] X[V_{sc}/V_{opt}]

=[(4.343 X105)/2.92] X[(6.14X10^{-9}/'153.38X10^{-6})=6dB/km

44. **A trigonometrically measurement is performed in order to determine the numerical aperture of a step index fiber. The screen is positioned 10.0cm from the fiber end face. When illuminated from a wide-angled visible source the measured output pattern size is 6.2cm. Calculate the approximate numerical aperture of the fiber. (CO4) (Applying)**

NA= $A/(A^2+4D^2)^{1/2}$ = $6.2/(38.44+400)^{1/2}$ = 0.30

45. **What is bit period ? (CO4) (Remembering)**

The transmitted signal is two level binary data stream consisting of either 0 or 1 in a time slot of duration T. This time slot is referred to a bit period.

46. **Define internal noise and its types? (CO4) (Remembering)**

Internal noise is caused by the spontaneous fluctuation of current or voltage in electric circuits. The two most common internal noises are (i) Shot noise and (ii) Thermal noise Shot noise arises in electronic devices because of the discrete nature of current flow in the device. Thermal noise arises from the random motion of electrons in a conductor.

47. **What do you mean by excess noise factor? (CO4) (Remembering)**

Excess noise factor is a measure of the increase detector noise that results from the randomness of the multiplication process. It depends on the ratio of the electron and hole ionization rates and on the carrier multiplication.

48. Write the functions of optical receivers. (CO4) (Understanding)

The receiver must first detect weak signal, distorted signals and then make decisions on what type of data was sent based on an amplified version of this distorted signal.

49. What are the stages available in an optical receiver? (CO4) (Understanding)

The three basic stages are (i) Photo detector (ii) An amplifier and (iii) An equalizer

50. Define equalizer. (CO4) (Remembering)

The equalizer is a linear frequency-shaping filter used to compensate the effects of signal distortion and inter symbol interference .It accepts the combined frequency response of transmitter, fiber and the receiver and transform it into a signal response that it suitable for the following signal processing.

51. How to evaluate a digital receiver performance? (CO4) (Understanding)

The digital receiver performance can be evaluated by measuring the probability of error and quantum limit. The dispersion produces pulse broadening of light wave signals in optical fibers, thereby limiting the information carrying capacity.

52. Mention the advantages of using transimpedance front and receiver configuration. (CO4)(Understanding)(Nov/Dec 2014)

i).Wide dynamic range ii). Little or no equalization is required iii). Less susceptible to pick up noise, crosstalk, EMI iv). It is very easily controllable and stable.

53. **What are the significance of photodiodes used in optical communication?(CO2) (Understanding)(June 2016, June 2018)**

The significance of photodiodes are i)High sensitivity at the operating wavelengths ii)Responsivity iii)Quantum efficiency iv)High fidelity v) Low bias voltage.

16 MARKS

1. Explain the operation of avalanche photodiode and pin photodiode. (CO4) (Understanding) (Apr/May 08), (May 2010),(Nov 10,Nov11, Nov 12),(Nov/Dec 2013) (Dec 2015,June 2016,Apr/May 2019)
2. The quantum efficiency of a particular silicon RAPD is 80% for the detection of radiation at a wavelength of 0.9μm, when the incident optical power is 0.5μW. The output current from the device is 11μA. Determine the multiplication factor of the photodiode under these conditions. (CO4) (Applying)(May 10)
3. Draw the circuit diagram of high impedance pre amplifier and explain its operation. (CO4) (Understanding)(Nov 08,June 12),(May 2010)
4. Discuss the source of errors in the optical receivers. (CO4) (Creating)(May 2010)
5. An InGaAs pin photodiode has the following parameters to wavelength of 1300nm: ID=4nA, η=0.9, RL=1000Ω and the surface leakage current is negligible. The incident optical power is 300nW (5dBm), and the receiver bandwidth is 20MHz. Find the various noise terms of the receiver. (CO4) (Applying)(Apr/May 05)
6. Discuss the requirement of optical detector. (CO4) (Creating)
7. A silicon p-i-n photodiode incorporated into an optical receiver has a quantum efficiency of 60% at a wavelength of 0.9μm. The dark current is 3nA and load resistance is 4KΩ. The incident optical power is 200nW and the receiver bandwidth is 5MHz. Determine i. mean square quantum noise current, ii. mean square dark current and iii. Mean square thermal noise current at a temperature of 20ºC. (CO4) (Applying)(Apr/May 2019)
8. Discuss with necessary expressions the different types of noise that affect the performance of a photo detector. (CO4) (Understanding)(May 13), (Nov/Dec 2014, June 2018,Apr/May2019)
9. When 3 x 10^{11} photons each with a wavelength of 0.85μm are incident on a photodiode, on the average 1.2 x 10^{11} electrons are collected at the terminals of the device. Determine the quantum efficiency and responsivity of the photodiode at 0.8μm. (CO4) (Applying)
10. Derive the expression for signal-to-noise ratio obtained at the output of an optical receiver. (CO4) (Understanding)(May 09, June 2018)
11. Describe the characteristics of responsivity against wavelength for an ideal silicon photodiode with the help of expression. Explain the direct and indirect absorption in Si and Ge. (CO4)

(Understanding) (Nov/Dec 09)

12. Discuss the various sources of noise that affect the performance of Optical receivers. Derive expression for the S/N of APD. (CO4) (Creating)(Nov/Dec 09)

13. Explain avalanche multiplication noise in detail. (CO4) (Understanding) (Nov 2012)

14. Explain the structure and working of silicon APD. (ii) Define S/N ratio of a photo detector. What conditions should be met to achieve a high SNR. (CO4) (Understanding) (Nov/Dec 2011)

15. (i) Draw the structure and electric fields in the APD and explain its working. (CO4) (Understanding) (Nov/Dec 2012)
(ii) What are the three factors that decides the response time of photodiodes? Explain them in detail with necessary sketches. (CO4) (Understanding) (Nov/Dec 2012), (Nov/Dec 2014)

16. Discuss in detail digital receiver performance calculation and sensitivity calculation. (CO4) (Creating)

17. What is known as quantum limit? A digital optic link operating at 850nm requires a maximum of 10^{-9}. Find the minimum incidental optical power P_0 to achieve this BER at a data rate of 10Mb/s for a simple binary level signaling scheme.($\eta = 1$, $1/\tau = B / 2$). (CO4) (Applying)

18. Discuss the performance of digital receiver by defining the probability of error. (CO4) (Understanding)

19. Discuss the fundamentals of receiver operation with neat block diagram. (CO4) (Understanding) (Nov 2012),(Nov 2013)(Dec 2015, June 2018)

20. Write brief note on transimpedance amplifier. (CO4) (Understanding) (June 12)

21. Derive the expression for probability of error (Pe) in a Digital receiver, with necessary diagrams. (CO4) (Understanding) (Nov/Dec 10)

22. Write short notes on quantum limit. (CO4) (Understanding) (Nov 2012)

23. i. Draw the front end optical amplifiers and explain. ii. Considering the probability distributions for received logic 0 and 1 signal pulses, derive the expressions for BER and error function. (CO4) (Applying) (Nov/Dec 2012), (May/June 2013)

24. i. Explain any two types of amplifier used in receiver. ii. Define the term quantum limit and probability of error with respect to a receiver with typical values. (CO4) (Understanding) (Nov/Dec 2013)

25. Discuss in detail digital receiver performance calculation and sensitivity calculation in detail. (CO4) (Creating)

26. Draw and explain the operation of high impedance FET and BJT preamplifiers. (CO4) (Understanding) (Nov/Dec 2011) (Dec 2015)

27. Explain the error sources of fundamental receiver operations. Discuss the performance of digital receiver by defining the probability of error. (CO4) (Understanding),(Nov/Dec 2014)

28. Explain the fiber optic receiver operation using a simple model and its equivalent circuit. (CO4) (Understanding) (Nov/Dec 2011)

29. Discuss the noise and disturbance affecting the optical detection systems. (CO4) (Creating)(May/June2012)

30. (i) Explain the fiber optic receiver operation using a simple model and its equivalent circuit.
(ii) Explain the operation of a pre-amplifier built using a FET. (CO4) (Understanding)

31. (i) Draw the front end optical amplifiers and explain(ii) Considering the probability distributions for received logic 0 and 1 signal pulses, derive the expressions for BER and error function. (CO4) (Understanding) (Nov/Dec 2012)

32. (i)A Silicon p-i-n photodiode Incorporate into an optical receiver has a quantum efficiency of 60% at a wavelength of 0.9 *f1*m, The dark current is 3 nA and load resistance is 4 Kiloohm. The incident optical power is 200 nw and the receiver and width is 5 MHz, Determine (1) mean square quantum noise current,(2) mean square dark current and (3) mean square thermal noise current at a temperature of 20°C.(ii) Draw and explain the operation of APD. (CO4) (Applying)(Nov/Dec 2007)

33. (i)Discuss the different noise sources and disturbances in the optical pulse detection mechanism.(ii) Derive an expression for the bit error rate of an optical digital receiver. (CO4) (Analyzing) (Nov/Dec 2009)

34. Discuss with necessary expressions the different types of noise that affect the performance of a photodetector (Understanding) (ii)When 3 x 10^{11} photons each with a wavelength of 0.85 µm incident on a photodiode, on average 1.2 x 10^{11} electrons *are* collected at the terminals of the device. Determine the quantum efficiency and responsivity of the photodiode at 0.85µm. (CO4) (Applying) (Nov/Dec 2009)

35. A PIN diode is characterized by a quantum efficiency of 60% at a wavelength of 900nm. Calculate responsivity of the PIN diode at 900nm.(Dec 2015) (CO2) (Applying)

36. The avalanche photodiode and the photo conducting detector both provide gain. Compare their merits for use in optical communication and other application.(CO2((Analyzing) (June 2016)

UNIT V -DIGITAL TRANSMISSION SYSTEMS

TWO MARKS

1. What are the factors to be considered in Link power budget?(CO5) (Remembering) (Nov/Dec 04)

The factors to be considered in link power budget are: i. transmission speed ii. optical sources & detectors iii. optical fiber.

2. What is meant by soliton? (CO5) (Remembering) (Apr/May 05), (Nov/Dec 10) (Nov 2012,May2019)

Soliton are pulses that travel along the fiber without change in shape or amplitude or velocity.T here are two types of soliton: 1. Fundamental soliton : The family of pulses that do not change in shape are called fundamental soliton. 2. Higher order soliton : The family of pulses that undergo periodic shape changes are called higher order soliton.

3. What is meant by modal noise? (CO5) (Remembering) (Apr/May 05)

It arises when the light from a coherent laser is coupled in to a multimode fiber operating at 400Mbps and higher. It mainly occurs due to mechanical vibrations and fluctuations in the frequency of the optical source.

4. List the system requirements needed in analyzing a point-to-point link. (CO5) (Remembering) (Nov/Dec 05),(Nov/Dec 10),(Nov 13, June 2018,MAY2019)

i. The desired transmission distance ii. The data rate or channel bandwidth iii. The Bit Error Rate (BER)

5. Discuss the concept of link power budget. (CO5) (Creating)(Nov/Dec 05)

In link power budget analysis, first determines the power margin between the optical transmitter output and the minimum receiver sensitivity needed to establish a specific BER Within this margin the connector, splice and fiber losses are allocated. It also require additional margins for possible component degradations, transmission – line impairments or temperature effect.

6. What are advantages of WDM? (CO5) (Remembering) (Nov/Dec 07), (Nov/Dec 10)

Capacity upgrade, transparency, wavelength routing and switching are the key advantages of WDM.

7. What is the significance of rise time budget? (CO5) (Remembering) (Nov/Dec 08)

The rise time budget analysis is a convenient method for determining the dispersion limitation of an optical fiber link. $t_{sys} =\sqrt{(t^2_{tx} + t^2_{mod} + t^2_{mat} +t^2_{rx})}$

8. Compare doped fiber amplifiers and conventional repeaters. (CO5) (Understanding)(Nov/Dec 08)

Repeaters	Fiber amplifiers
i.Amplification done conversion of optical to electrical and amplify this signal and reconvert of electrical to optical ii. Used in short distance. iii. Complexity in this device iv. Bandwidth utilization is less.	i. Its directly amplify the optical signal without any conversion. ii. Used in long distance iii. less complexity iv. Bandwidth utilized effectively.

9. Define mode partition noise. (CO5) (Remembering) (May/June 09)

The mode partition noise is associated with intensity fluctuations in the longitudinal modes of a laser diode. It becomes more pronounced for the higher bit rates.

10. What are the advantages of using soliton signals through fiber? (CO5) (Remembering)

Solitons are very narrow, high intensity optical pulses that retain their shape through the interaction of balancing pulse dispersion with the non linear property of an optical fiber. The pulse broadening effects of GVD is overcome by silicon pulse transmission.

11. **List the two analyses that are used to ensure system performance? (June 2016)(CO5) (Remembering)**

The two analysis that are used to ensure system performance are :i. link power budget analysis ii. rise time budget analysis

12. **Give the range of system margin in link power budget? (June 2016)(CO5) (Understanding)**

The system margin is usually (6-8) dB. A positive system margin ensures proper operation of the circuit. A negative value indicates that insufficient power will reach the detector to achieve the required bit error rate, BER.

13. The specifications of the light sources are converted to equivalent rise time in rise time budget. Why? (CO5) (Analyzing)

A rise time budget is a convenient method to determine the dispersion limitation of an optical link. This is particularly useful for digital systems. For this purpose, the specifications of the light sources (both the fiber & the photo detector) are converted to equivalent rise time. The overall system rise time is given in terms of the light source rise time, fiber dispersion time and the photo detector rise time.

14. What are the system components of system rise time? (CO5) (Remembering)(Dec 2015)

The 4 basic system components that contribute to the system rise time are: i. transmitter (source) rise time ii. Receiver rise time iii. Material dispersion time of the fiber iv. Modal dispersion time of the fiber link .All these four basic elements may significantly limit system speed.

15. What are the noise effects on system performance? (CO5) (Remembering)

The main penalties are modal noise, wavelength chirp, spectral broadening and mode-partition noise.

16. What are the measures to avoid modal noise? (CO5) (Understanding)(Nov/Dec 10)(Dec 2015)

The measures are i. use LEDs ii. use LASER having more longitudinal modes iii. use a fiber with large numerical aperture iv. use a single mode fiber

17. What is meant by chirping? (CO5) (Understanding)(Nov/Dec 09)

It means that the dynamic line broadening (line broadening is a frequency chirp) in the laser which oscillates in the single longitudinal mode under CW operation when the injection current is intensity modulated.

18. What is the best way to minimize the chirping? (CO5) (Remembering)

It is to choose the laser emission wavelength close to the zero-dispersion of the wavelength of the fiber.

19. What is reflection noise? (CO5) (Remembering)

It is the optical power that gets reflected at the refractive index discontinuities such as in splices, couplers and filters, or connectors. The reflected signals can degrade both the transmitter and receiver performance.

20. What are the effects of reflection noise in high speed systems? (CO5) (Remembering)

They cause optical feedback which leads to optical instabilities that may lead to intersymbol interference and intensity noise.

21. What are the basic performances of the WDM? (CO5) (Remembering)

i. Insertion loss ii. Channel width iii. Cross talk

22. What is WDM? (CO5) (Understanding)(Nov 2012, June 2018)

WDM is wavelength division multiplexing. The optical beam consists of different wavelengths and several channel information is transmitted over a single channel.

23. What is meant as bidirectional WDM? (CO5) (Understanding)

A single WDM which operates as both multiplexing and demultiplexing Devices is said as the bidirectional WDM.

24. What is the use of power budget in fiber optic system? (CO5) (Understanding)

The power budget is used to determine the power margin between the optical transmitter output and the minimum receiver sensitivity needed to establish a specified BER.

25. What is the use of rise budget in fiber optic system? (CO5) (Understanding)

The rise time budget is used to verify that the overall system performance requirements like maximum bit rate and maximum transmission distance.

26. What is SONET? (CO5) (Remembering)

Synchronous Optical Network (SONET) is a standard developed by ANSI for fiber optic networks. SONET defines a frame structure for transmitting TDM signals in the optical fiber networks. It encodes bit streams into optical signals that are propagated over optical fiber.

27. What is relation between STS and OC levels? (CO5) (Analyzing)

SONET has defined a hierarchy of signals called Synchronous Transport Signals (STS). Optical (OC) levels are the implementation of STSs or the physical links defined to carry each level of STS are called Optical Carriers (OCs).

28. What is DWDM? (CO5) (Remembering)

Dense Wavelength Division Multiplexing (DWDM) is an optical technology used to increase bandwidth over existing fiber – optic backbones. DWDM works by combining and transmitting multiple signals simultaneously at different wavelengths on the same fibers.

29. What is meta stable state? (CO5) (Remembering)

The meta stable means that the lifetimes for the transitions from this state to the ground state are very long compared with the lifetimes to the states that led to this level.

30. What is stark splitting? (CO5) (Remembering)

The meta stable, the pump, and the ground state levels are actually bands of closely Spaced energy levels that form manifold due to the effect known as stark splitting.

31. **What are the techniques used for minimizing reflection noise? (CO5) (Understanding) (Nov/Dec 09)**

i. Prepare fiber end surfaces with a curved surface or an single relative to the laser emitting facet. This directs reflected light away from the fiber axis. ii. Use index matching oil or gel at air glass interface. iii. Use connectors in which end faces make physical contact. Iv. Use optical isolators within the laser transmitter module.

32. Mention the significance of WDM.(CO3) (Understanding) (June 2016)

WDM is wavelength division multiplexing. The optical beam consists of different wavelengths and several channel information is transmitted over a single channel. Capacity upgrade, Transparency, Wavelength routing is features of WDM. The basic performance of WDM is i). Insertion loss ii). Channel width iii). Cross talk.

16 MARKS

1. Discuss the principle of WDM with example and neat block diagram. (CO5) (Understanding)(Nov 2012),(Nov 2013) (Dec 2015),(Apr/May2019)
2. Explain the rise-time budget of a fiber optic point-to-point link. (CO5) (Understanding) (Nov/Dec 10, Nov 2012, Nov 13) (Dec 2015, June 2018,Apr/May2019)
3. Draw the point-to-point fiber optic link and discuss the system considerations. (CO5) (Remembering)(June 12, Nov 13, June 2018)
4. Discuss the noise effects on fiber optic system performance. (CO5) (Creating)
5. Explain the principle of operation of erbium doped amplifier. (CO5) (Understanding)(EDFA).
6. Give brief account of the principles of SONET/SDH. (CO5) (Understanding)(Nov/Dec 10, Nov 2012) (Dec 2015)
7. Explain the salient features of solitons using relevant expressions and diagrams. (CO5) (Evaluating) (June 2018)
8. Give a brief account of the different types of losses to be considered in the design of an optical link. (CO5) (Understanding)
9. Draw and explain the basic format of an STS-N SONET frame. (CO5) (Remembering)
10. Derive the expression for EDFA quantum conversion efficiency and amplifier gain. (CO5) (Analyzing)(Nov/Dec 09)
11. Explain the amplification mechanism in EDFA. Discuss the possible configuration of EDFA with neat diagram. (CO5) (Understanding)(Nov 2012) (Dec 2015)
12. Draw the soliton pulse and its envelop and describe its fundamental and its propagation in optical fibers. (CO5) (Understanding)(Nov/Dec 09, Nov 13)
13. Explain SONET layers with neat diagrams. (CO5) (Remembering)(Nov/Dec 09)
14. Describe the operation of Unidirectional and bidirectional WDM. (CO5)(Understanding) (Nov/Dec 09)
15. What are link power budget and rise time budget analyses? Perform these analyses for a fiber link that uses a conventional single mode fiber that has been upgraded by DCF loops and optical amplifiers.(CO5) (Understanding) (June 2016)
16. Outline EDFA designs incorporating both a CO – and Counter propagating pump. State the main advantages of each configuration.(CO5)(Understanding)(June 2016)
17. Identify the key requirements needed for designing an optimal optical link and the choice of components for fulfilling it. Discuss the implementation of a typical WDM link with various components and different types of amplifiers. (CO5)(Understanding)(Apr/May 2019)