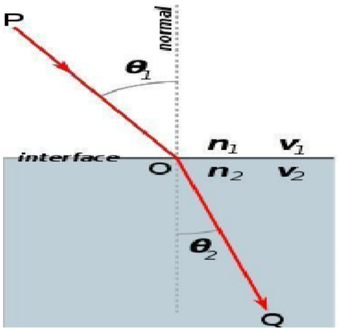
UNIT-I-INTRODUCTION TO OPTICAL FIBERS

PART A

1. State Snell's law. (May '15)

In optics and physics, **Snell's law** or the **law of refraction**), is a formula used to describe the relationship between the angles of incidence and refraction, when referring to light or other waves, passing through a boundary between two different isotropic media, such as water and glass. The law says that the ratio of the sines of the angles of incidence and of refraction is a constant that depends on the media.



$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

In optics, the law is used in ray tracing to compute the angles of incidence or refraction, and in experimental optics to find the refractive index of a material.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \; .$$

2. Give refractive index expression for step index fiber

For step index fiber, the refractive index is expressed as

$$n_2 = n_1(1-\Delta)$$

where n_2 - refractive index of cladding , n_1 –refractive index of core and

– the core-cladding index difference.

3. It is desired to make a single-mode fiber at an operating wavelength=1300 nm with n_{core}=1.505 and n_{clad}= 1.502.Find the Numerical Aperture and core radius. (Dec'06) (May '14)

Numerical Aperture = $(n_{core}^2 - n_{clad}^2)^{1/2} = (1.505^2 - 1.502^2)^{1/2}$ = 0.094979

Numerical Aperture = v. λ/2πa , v = 2.405,

Core radius (a) = v.λ/2π(Numerical Aperture) = 5239nm.

4. Give the refractive index expression of a graded index fiber. (Dec '06)

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

$= n_1[1-2\Delta]^{1/2} = n_1[1-\Delta] = n_2$ for $r \ge a$

5. Define Numerical Aperture of a step index fiber. (Dec'14)

Numerical aperture is the light gathering capability of a fiber. It is related to the refractive indices of core and cladding. For step index fiber it is expressed as

$$NA = (n_{core}^2 - n_{clad}^2)^{1/2}$$

6. Define Mode-field diameter.

Mode-field diameter is defined as the diameter of the one mode of light that is being propagated in a single-mode fiber. It is determined from the mode-field distribution of the fundamental LP_{01} mode.MFD is an expression of distribution of the irradiance, *i.e.* , the optical power, across the end face of a single - mode fiber. *Note:* For a Gaussian power distribution in a single-mode optical fiber, the mode field diameter is that at which the electric and magnetic field strengths are reduced to 1/e of their maximum values, *i.e.,* the diameter at which power is reduced to $1/e^2$ of the maximum power, because the power is proportional to the square of the field strength.

7. A point source of light if 12 cm below the surface of a large body of water (n=1.33). What is the radius of the largest circle on the water surface through which the light can emerge? Find θc from Snell's law.

n1*sinθ1=n2*sinθ2=1, n2=1.33, then θc=48.75 degree

Find r from tan θc= r / 12cm, r =13.7 cm.

8. Commonly available single mode fibers have beat lengths in the range 10 cm < Lp<2 m. What range of refractive index differences does this correspond to (for λ = 1300 nm)? (May '06)

L_1 = 10cm = 0.1m

$B_{f1} = n_y - n_x = \lambda / L_1 = 1300 \times 10^{-9}/0.1 = 1.3 \times 10^{-5}$

L_2 = 2m

$B_{f2} = \lambda / L_1 = 1300 \times 10^{-9}/2 = 6.5 \times 10^{-7}$

The range of refractive index differences varies between 6.5 x 10^{-7} to 1.3 x 10^{-5}

9. What are the major elements of an optical transmission link?

(a) Light signal transmitter (b) Optical fiber (Transmission channel)

(c)Photo detecting receiver. Additional elements include Splices and connectors, regenerators, beam splitters and optical amplifiers.

10. Write down the wavelength regions corresponding to 1^{st} 2^{nd} and 3rd windows.

(a)1^{st} window-800-900nm,(b)2^{nd} window-1100-1350nm,(c)3^{rd} window-1500-1650nm

11. What are the two principal photo detectors used in a fiber-optic link?

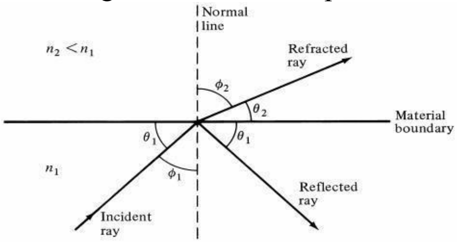
(a) Semiconductor P-I-N ,(b) Avalanche photodiode.

12. What's meant by refractive index of a material?

The ratio of the speed of light in vacuum to that in matter is the refractive index of the material and is given by n=c/v =Velocity of light in Vacuum/Velocity of light in matter.

13. What's critical angle of incidence?

If the angle of incidence Φ_1 is increased a point will eventually be reached where the light ray in air is parallel to the glass surface. This point is known as critical angle of incidence Φ_c.



14. Explain whether cladding is necessary.

Yes. It is necessary because,

(i) the light can be confined within the core, (ii) It can add additional mechanical strength.
(iii) It reduces scattering loss, (iv) It protects the core from absorbing surface contaminants.

15. What types of fibers are used commonly?

(a) Based on refractive index profile- (i) Step index (ii) Graded index

(b) Based on propagation-(i) Mono-mode or single mode (ii) Multimode

16. What are all the advantages offered by multimode fibers than single mode fibers? Advantages:

(a) A larger core radii of multimode fibers makes launching optical power into the fiber easier.

(b) It also facilitates the connection of similar fibers.

(c) LED can be used as a source.

Disadvantage: They suffer from intermodal dispersion.

17. What is cut-off condition?

The boundary between truly guided modes and leaky modes is defined by the cut off condition $\beta = n_{clad}k$. A mode remains guided as long as β satisfies the condition $n_{clad}k < \beta < n_{core}k$ where $k = 2\pi/\lambda$

19. Consider a parabolic index waveguide with n_1 =1.75, n_2 =1.677and core radius 25µm. Calculate the numerical aperture at the axis and at a point 20 µm from the axis.

At axis: Numerical Aperture (NA(0)) = $(n_{core}^2 - n_{clad}^2)^{1/2}$ = 0.5

This is the numerical aperture, it does vary at the centre at a point 20 µm from the axis.

NA(0)$\{1-(r/a)^{\alpha}\}^{1/2}$ = 0.5$\{1-(20/25)^2\}^{1/2}$ = 0.3 (Where α = 2 since profile is parabolic)

20. What are the advantages and disadvantages of the ray optics theory? (Nov '08) 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 curve fiber,
(ii)It does not solve the interference problem
(iii)Inaccurate for non-zero wavelength unit when number of guided mode is large.

20. For a fiber with core refractive index of 1.54 and fractional refractive index difference of 0.01,calculate its numerical aperture(Nov/Dec-2013)

Solution : n1=1.54 , = 0.01

NA = $n_1 (2)^{1/2}$ = 1.54$(2 \times 0.01)^{1/2}$=0.218

21.For n1=1.55 and n2= 1.52, calculate the critical angle and Numerical aperture.(May'13) (May '15)

Solution : NA= $(n_1^2-n_2^2)^{1/2}$ = 0.3035

Critical angle $Ø_C=\sin^{-1}(n_2/n_1)$ = 17.4^o

22.What is a linearly Polarised mode ?(May-2013)

In electromagnetics, linear polarization or plane polarization of electromagnetic radiaton is a confinement of the electric field vector or magnetic field vedctor to a given plane long the direction of propagation.

23. List any two advantages of single mode fibers.(Nov '14)

1. Intermodal dispersion is absent. 2. supports larger bandwidth.

24. Determine the normalized frequency at 820 nm for a step inex fiber having a 25μm radius.The refractive indexs of the clading and core are 1.45 and 1.47 respectively. How many modes propagate in this fiber at 820nm ? (Nov '13)

Solution : Normalized frequency is given by,

V=(2π/ƛ)a(NA)

Numerical Aperture = ^{2} - $n_{clad}^2)^{1/2}$ = $(1.47^2-1.45^2)^{1/2}$ = 0.255 (n_{core}

Normalized frequency = (6.18/820nm)(25μm)(0.255)=4.18KHz.

25.Distinguish meridional rays and skew rays. (May '14)

Meridional rays	Skew rays
1) Meridionial rays pass through the fiber axis	Skew rays doesn‟t pass through the fiber axis
2) Meridional rays follows zig zag path	Skew rays follow helical path

26. What is total internal reflection in a fiber ? (Nov '15)

a) Light should travel from denser medium to rarer medium.

b) The angle of incidence should be greater than the critical angle of the denser medium.

27. Define phase and group delay. (Nov '15)

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‟.

PART B

1. What are the different types of fibers depending on refractive index profile? **(Nov '15)**
2. (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 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**.(Dec-11) (May '15)**
3. (i) Explain the differences between meridional and skew rays.
   (ii)Explain briefly Phase and Group Velocities **(Nov 2013)**
4. A graded index fiber has a core with a parabolic refractive index profile which has a diameter of 50μm . The fiber has a numerical aperture of 0.2. Estimate the number of guided modes propagating in the fiber when it is operating at a wavelength of 1μm.
5. (i) Explain the phenomenon of total internal reflection using snell‟s law with figures and calculations.

   (ii)Distinguish Step-index from graded index fibers**.(Nov-2011) (May '15)**
6. (i) Calculate the refractive indices of the core and the cladding materials of an optical fiber Whose NA = 0.35 and A = 0.01.(**May-2013**)
   (ii)Determine the cut off wavelength for a step index fiber to exhibit single mode operation

   when the core refractive index and radius are 1.46 and 4.5 μm respectively with the relative index difference being 0.25%.
7. Explain the modes in Planar Guide briefly.
8. (i)Consider a fiber with diameter 8μm , n_1 and = 0.92%. If this fiber is operated at 1550 mm, how many modes will it have?
   (ii) Explain SM fibers in detail.
9. (i)Calculate the diameter of the fiber core of relative refractive index difference is 10%, core refractive index n1 = 1.5, No. of modes propagation is 1100 and wavelength of operation is 1.3 μm, (ii) Write short notes on Cylindrical Fibers.
10. Draw the block diagram of a fiber optic communications system and describe function of each component. **(Nov 2013)**
11. Derive the mode equation for a circular fiber using Maxwell‟s equations**.(May-2013)**
12. Describe single mode fibers and their modes-field diameter. What are the propagation

modes in them? **(May-2013)**

13. (i) Define the normalized frequency for an optical fiber and explain its use**.(Nov-14**)
    (ii) Discuss on the transmission of light through graded index fiber. **.(Nov-14)**
14. Explain the features of multimode and single mode step index fiber and compose them**.(Nov'14)**
15. (i) Draw and explain ray theory transmission in an optical communication.
    (ii) With diagram explain acceptance angle numerical aperture and total internal reflection**. (May '14) (Nov '15).**
16. With diagram explain Electromagnetic mode theory of optical propagation**.(May '14) (Nov '15).**

UNIT-II-SIGNAL DEGRADATION OPTICAL FIBERS
PART A

1. **What does signal attenuation determine?**

Signal attenuation largely determines the maximum repeater less separation between aTransmitter and a receiver.

2. **What's the effect of dispersion in an optical fiber?(Nov-2013)**

The dispersion mechanisms in a fiber cause optical signal pulses to broaden as they travel along a fiber.

3. Define signal attenuation.(Nov-2013) (May/June'15)

Signal attenuation is defined as the ratio of the optical output power P_{out} from a fiber of length L to the optical input power P_{in}

Attenuation (α)=10/L log{P_{in}/P_{out}}dB/Km

4. How is absorption caused in a fiber?

Absorption is caused by 3 different mechanisms.
(a)Absorption by atomic defects in the glass composition.
(b)Extrinsic absorption by impurity atoms in the glass material.
(c)Intrinsic absorption by the basic constituent atoms of the material.

5. What are atomic defects?

Atomic defects are imperfections 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.

6. How does impurity absorption loss occur?

Impurity absorption loss occurs either because of electronic transitions between the energy levels associated with the incompletely filled inner sub shell of these ions or because of charge transitions from one ion to another.

7. **What are the materials that predominantly take part in impurity absorption?**
Transition metal ions such as iron, chromium, cobalt, copper, and OH (water) ions.

8. **How does intrinsic absorption occur?(Nov/Dec-14)**

The intrinsic absorption occurs when the material is in perfect state with no density variations, impurities, material inhomogenities etc. Intrinsic absorption thus sets the fundamental lower limit on absorption for any particular material.

9. What's Urbach's rule?
The UV edges of the electron absorption bands of both amorphous and crystalline materials follow the empirical relationship, $\alpha_{UV}=Ce^{E/E_0}$ which"s known as Urbach"s rule. Here C and E0 are empirical constants and E is the photon energy.

10. **Identify the causes of scattering loss. (May '14)**

Scattering losses in glass arise from microscopic variations in the material density, from compositional fluctuations, and from structural inhomogenities or defects occurring during fiber manufacture.

11.**What are the types of bends that can be subjected to a fiber? (May '15)**
Two types of bends-

(i) Macroscopic bends having radii that are larger compared to the fiber diameter (ii) Random microscopic bends of the fiber axis that can arise when the fibers are incorporated into cables

12. What are micro bends? How are they caused in the fiber?

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

13. **Why does an increase in attenuation result from micro bending?**

An increase in attenuation results from micro bending because the fiber curvature causes repetitive coupling of energy between the guided modes and the unguided modes in the fiber.

14. How can you minimize micro bending losses?

Micro bending losses can be minimized by extruding a compressible jacket over the fibre. When external forces are applied to this configuration, the jacket will be deformed, but the fiber will tend to stay relatively straight.

15. What are the two main causes of intra modal dispersion?

(a)Material dispersion**,** (b)Waveguide dispersion

16. How does waveguide dispersion occur?

Waveguide dispersion occurs because a single mode fiber only confines about 80% of the optical power to the core. The 20% of the optical power travels in the cladding because of the speed difference between these two dispersion occurs.

17. List the basic attenuation mechanisms in an optical fiber. (Dec '14)

1.Absorption, 2.Scattering, 3.Radiative losses of the optical energy 4. Bending Losses

18. What is meant by mode coupling? What causes it? (May '06, Nov '06)

Coupling energy from one mode to another is called mode coupling. It arises because of structural imperfections, fiber diameter and refractive index variations and cabling induced in micro bends.

19. **What are the causes of absorption? (May '05)**

Absorption is caused by 3 different mechanisms.

(a)Absorption by atomic defects in the glass composition. (b)Extrinsic absorption by impurity atoms in the glass material. (c)Intrinsic absorption by the basic constituent atoms of the material.

20. **An optical signal has lost 55%of its power after traversing 3.5 km of fiber. What is the loss in dB/km of this fiber? (Dec '04, May '14)**

Attenuation (α) =10/L log{P_{in}/P_{out}}dB/Km = 10/3.5log(1/0.45) = 0.992db/km

21. Give the expression of the effective number of modes that are guided by a curved multimode fiber of radius 'a'. (Dec '04, May'05, Nov'05)

$N_{eff} = N_\infty\{ 1- (\alpha+2)/(2\alpha\Delta)[(2a/R)+(3/2n_{clad}kR)^{2/3}]\}$

Where α defines the graded index profile

is the core-cladding index difference, k is the propagation constant R is the radius of the curvature of the bent fiber.

a is the fiber core radius

N_∞ is the total number modes in straight fiber.

22. Define normalized propagation constant. (Dec '05)

Normalized propagation constant is defined by

$b = \{\beta^2/k^2-n^2_{clad}\}/ \{n^2_{core} - n^2_{clad} \}$

Where k is propagation constant

23. Define Group delay (Nov '08)

I t is defined as the ratio of distance travelled by pulse to the group velocity, $\tau_g = L/V_g$

24. What is Rayeligh Scattering? (May '13)

This scattering occurs in all directions and produces an attenuation proportional to $1/\lambda^4$. This loss occurs in the ultra violet region.It tail extends up to infrared region.

25.What is Mode Coupling?

It is another type of pulse distorsion which is common in potical links.The pulse distortion will increase less rapidly after a certain initial length of fibre due to this mode coupling and differential mode losses.In initial length coupling of energy from one mode to another arises because of structural irregularities,fibre dia. etc.

26.What is Profile Dispersion?

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

27.What is M-C fiber?

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

28.What is D-C fiber?

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

29.Define depression 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 wavelenth. The resulting optical fiber are known as dispersioin shifted fiber.

30.Define dispersion flattening?

The reduction of fiber dispersion by spreading the dispersion minimum out over a widen range .this approach is known asd dispersion flattering.

31.What is effective cut-off wavelenth?

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

32.What do you mean by polarization dispersion in a fiber? (Nov '15)

The difference in propagation times between the two orthogonal polarization modes will result in pulse spreading. This is called as polarization Mode Dispersion.

33.A fiber has an attenuation of 0.5 dB/Km at 1500nm. If 0.5mW of optical power is initially launched into the fiber, what is the power level in after 25Km? (Nov'15)

$P(z) = P(0) \exp(-\alpha z) = 7.581\mu W$

PART B

1. (i)What is signal attenuation in an optical fiber ? What is the unit of attenuation?
   (ii)With the help of suitable diagrams, explain in detail basic attenuation loss mechanisms. **(May '14) (May '15) (Nov '15)**.
2. (i)What do you mean by Dispersion?
   (ii) Explain in detail chromatic dispersion in single mode fibers.
3. Clearly bring out the differences between intra and inter modal Dispersion with necessary diagrams. **(Nov '13, May '14**)
4. Discuss the attenuation encountered in optical fiber communication due to: Bending ,Scattering, Absorption **(Nov '13)**
5. What do you meant by pulse broadening? Explain its effect on information carrying capacity of a fiber**. (Nov '11)**
6. Describe linear scattering losses in optical fibers with regard to (i) Rayleigh scattering
   (ii) Mie scattering.
7. Explain stimulated Brillouim and Raman scattering in optical fibers and indicate the ways in which they can be avoided in optical fiber communication.
8. i)Derive expression for material dispersion and waveguide dispersion and explain them. **(Nov '15)**
   ii)Descrie various fiber connectors and couplers**. (May '13)**
9. (i)What is meant by critical bending radius of optical fibers? Explain **(Nov '14)**
   (ii) Explain the following in single mode fiber: Modal birefringence and beat length.
10. (i) Describe the three types of fiber misalignment that contribute to insertion loss at an optical fiber joint**.(Nov '14)** (ii) Outline the major categories of multiport fiber optic coupler**.(Nov '14)**

UNIT III-FIBER OPTICAL SOURCES AND COUPLING

PART A

1. Mention any four required properties of light sources used in the optical communication.

1.High radiance output, 2.Fast emission response time

3.High quantum efficiency, 4.Dimensional characteristics compatible with those of optical fibers.

2. What are the laser light properties? How are they produced?

1.High radiance output,2.Fast emission response time

3.High quantum efficiency. Dimensional characteristics compatible with those of optical fibers.High radiance and high quantum efficiency are achieved through carrier and optical confinement using double hetero structure.

3.Why laser emission is not obtained in an atomic system under thermal equilibrium?

In thermal equilibrium the density of excited electrons is very small. Most photons incident on the system will therefore be absorbed, so that stimulated emission is negligible, hence there is no laser emission.

4.What is meant by laser action? What are the conditions to achieve it?

Laser action is the result of three key processes

1). Photon absorption, 2). Spontaneous emission , 3). Stimulated emission

The conditions to achieve laser action are

1. Magnitude of guided mode should be greater than the threshold value.

2. At the lasing threshold, a steady state oscillation takes place, and the magnitude and phase of the returned wave must be equal to those of the original wave.

5. What is meant by threshold condition for laser oscillation?

Threshold condition for laser oscillation means that the pumping source that maintains population inversion must be sufficiently strong to support or exceed all the energy-consuming mechanisms within the lasing cavity.

6.What are direct band gap and indirect band semiconductors? (May '06, Nov '06, Nov '08)

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 from valence band to conduction. e.g.silicon, germanium.

7. **Mention the important semiconductors used in laser and LED's.**

1).GaAs, 2).InP, 3).InGaAs, 4).GaAlAs

8. What are the drawbacks of homo-junction laser diode

1). No carrier confinement 2). No optical confinement

9. Define internal quantum efficiency of a LED (Nov '14) (May '14) (Nov '15)

The internal quantum efficiency in the active region is the fraction of electron hole pairs that recombine radiatively. It"s given by $\eta_i = R_r / (R_r + R_{nr})$

Where, η_i is the internal quantum efficiency,R_r is the radiative recombination per unit volume. R_{nr} is the non radiative recombination rate.

10. Why do we prefer laser diodes over LED's for communication applications?

1.High intensity radiation 2. Narrow spectral width of the laser source are the preferable features of Laser compared to LED.

11. Why gain guided lasers are not used in practice?

1. Highly unstable, 2. Highly astigmatic

12. **What are the merits of index guided lasers?**

Index guided laser supporting only fundamental transverse mode and longitudinal mode is known single mode laser. Such a device emits a single well collimated beam of light having bell shaped Gaussian intensity profile.

13. Explain the radiation pattern from surface emitting laser diode or LED.

The emission pattern is isotropic with a 120 degree half-power beam width, i.e., source is equally bright when viewed from any direction, but the power diminishes as cosθ, where θ is the angle between the viewing direction and normal to the surface

14. Mention any four factors which affect the power launched into the fiber.

1).Numerical aperture 2).Core size 3).Refractive index profile,4).Core and Cladding index difference Size, 5).Radiance and angular power distribution of the source.

15. W**hat are the different factors that determine the response time of photo detector?** i)The transit time of the photo carriers 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.

16.Mention the important photo detector material. Why it is preferred?

1).InGaAs,2)InAlGaAs.These materials are preferred generally due to their inert optical property.

17.**What are the different components of an optical receiver?**

1).Photo deteor,2).Amplifier and 3).Signal processing circuitry.

18.**Why do prefer digital transmission rather than the analog transmission?**

Digital transmission has several advantages over analog transmission:

1. Analog circuits require amplifiers, and each amplifier adds distortion and noise to the signal. Subsequent stages may amplify the incoming signal and noi se as well.

2.In contrast, digital amplifiers regenerate an exact signal, eliminating cumulative errors. An incoming (analog) signal is sampled, its value is determined, and the node then generates a new signal from the bit value; the incoming signal is discarded.
3. Voice, data, video, etc. can all carried by digital circuits.

19. Write two differences between a Laser and a LED.(Nov-2013)

Sl.No	LED	LASER
1.	Optical output is in coherent	Optical output is coherent
2.	Output radiation has broad spectral width	Highly Monochromatic

20. What are the system requirements?

The following are the key system requirements.

1.The desired or possible transmission distance 2. The data rate or channel bandwidth

3. Bit error rate(BER)

21. What are splices? What are the requirements of splices?

The splices are generally permanent fiber joints, whereas connectors are temporary fiber joints. Splicing is a sort of soldering. The requirements of splices are:

1. Should cause low attenuation 2. Should be strong & light in weight
3. Should have minimum power loss 4. Should be easy to install

22. What are the methods of fiber splicing?

There are 3 methods of fiber splicing. They are:

1. Electric arc fusion splicing or fusion splicing 2. Mechanical splicing
3. V-groove splicing or loose tube splicing

23. What are connectors? What are the types of connectors?

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 2 major types of connectors are:

1. Lensed type expanded beam connector 2. Ferrule type connector

24. What are the requirements of a good connector?

The requirements of a good connector are as follows:

1. Low loss 2. Repeatability 3. Predictability 4. Ease of assembly and use
5. Low cost & reliability 6. Compatibility

25. Distinguish between splice and connector.

SPLICE	CONNECTOR
1. A permanent joint formed between two individual optical fibers in the field or factory.	In order to maintain an optimum performance the connection must also protect the fiber ends from damage which may occur due to handling (connection and disconnection), must be insensitive to environmental factors (e.g. moisture and dust) and cope with tensile load on the cable.
2. It is used to establish long-haul optical fiber links where smaller fiber lengths need to be joined, and there is no requirement for repeated connection and disconnection.	The connector design must allow for repeated connection and disconnection without problems of fiber alignment, which may lead to degradation in the performance of the transmission line at the joint.

26. What is mean by hetero junction structure? (Nov '15)

To achieve carrier and optical confinement, two different alloy layers on each side of active region is known as hetero junction structure.

PART B

1. i)What are direct band gap and indirect band, gap semiconductors?
   (ii) Describe the operation of LED? **(May '15)**
2. Explain surface emitting LED (SLED) and an edge emitting LED (ELED) in detail.
   (May '13, May '14)
3. Derive an expression for internal quantum efficiency of LEDS and LED power and external quantum efficiency. **(May '15)**
4. (i)What are the advantages and disadvantages of Lasers?
   (ii)What are the differences between spontaneous and stimulated emission of radiation.
5. Discuss about optical detection Noise. **(May '15) (Nov '15)**
6. Discuss coupled cavity semiconductor lasers and tunable semiconductor lasers.
7. Briefly explain the different noise sources of a photodetector. **(Nov '13)**
8. Explain the structure and working of a silicon PIN and Avalanche photo diode. **.(May '14)**
9. What do you understand by optical wave confinement and current confinement in LASER diode? Explain with suitable structures.(**Nov '13**)
10. A double hetrojunction In Ga ASP LED emitting as a peal wavelength of 1310 nm has radiative and non-radiative recombination times of 25r and 90 ns respectively. The derive current is 3,5 mA. (i) Find the internal quantum efficiency and internal power level.
    (ii) If the refractive index of the light source material is n = 3.5. Find the power emitted from the device.

11. (i) Describe the operation of a injection laser. **(Nov '14)**

    (ii) Compare the optical sources LED and ILD.**(Nov '14) (Nov '15)**

12. (i)What are the possible noise sources that contribute the photodetector noise? **(Nov-14)**

    (ii) What is meant by detector response time? Explain. **(Nov '14) (May '15)**

13. What are the main requirements of a good connector? Explain fiber splice and fiber connector in detail. **(May '15) (Nov '15)**

UNIT IV-FIBER OPTICAL RECEIVER AND MEASUREMENTS

PART A

1.What are the requirements of an optical receiver? (MAY'06)

a).Light detector b).Pre amplifier

c).Equalizer d).Signal discriminator circuits

2.What are the requirements for a preamplifier?

a).Preamplifier bandwidth must be greater than or equal to signal bandwidth.
b).It must reduce all source of noise, c).It must have high receiver sensitivity.

3.Why do we prefer trans-impedance preamplifier rather than high impedance preamplifier? (Nov '14)

Since the high impedance produces large input RC time constant, the front end bandwidth is less than the signal bandwidth. This drawback is overcome in the trans impedance preamplifier.

4.What are the main advantages of InGaAs photodiodes?

a). Wider operating wavelength range.(1100 to 1700nm) b). High responsivity(0.75 to 0.95 Amp/watts for PIN) c).Less dark current.(0.5 to 2nA) d).Less rise time(0.05 to 0.5ns) e).Lagerer bandwidth.(1 to 2GHz)

5.What are the various error sources in the optical receiver?(Nov-2012) (May-June'14)

a).Photon detection quantum noise , b).Bulk dark current noise

c).Surface leakage current, d).Statistical gain fluctuation(for APD)
e).Thermal noise, f).Amplifier noise

6.Define probability of error. Write an expression for it.

The probability of error is defined as $P_e = a P_1(v_{th}) + bP_0(v_{th})$ Where a and b are weighting factors,

$P_1(v_{th})$ – Probability that the equalizer output voltage is less than v_{th} when a logical one pulse is sent.

$P_0(v_{th})$ - Probability that the equalizer output voltage exceeds v_{th} when a logical zero pulse is transmitted.

7. Define quantum limit. (May '14, Nov '13)

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.

8..Define BER. (May '15)

An approach is to divide the number N_e of errors occurring over a certain time interval t by the number N_t of pulses transmitted during this interval. This is called either the error rate or the bit error rate.

Bit error rate BER $=N_e/N_t = N_e /Bt$ Where $B= 1/T_b$

9.A given APD has a quantum efficiency of 65%at a wavelength 900nm. If 0.5 µW of optical power produces a multiplied photocurrent of 10 µA, find the multiplication factor M (May '05)

$I_p = RP_o = (\eta q/h\nu)\, P_o = (\eta q\lambda/hc)\, P_o$

$= \{(0.65)(1.6 \times 10^{-19})(9 \times 10^{-7})/(6.625 \times 10^{-34} \times 3 \times 10^{8})\}5 \times 10^{-7} =$

0.235µA The multiplication factor(M) = I_m / I_p = 10µA/0.235µA = 43

10.Define Responsivity. (Nov '04, May'05, Nov'05, Nov'08,May'08) R

$= I_p/P_0 = \eta q/h\nu$

where I_p-average photocurrent generated,P_0- incident optical power level & η -quantum efficiency

11.Express quantum limit in terms of minimum power and S/N ratio at the receiver.

Assume that an optical pulse of energy E falls on the photodetector in a time interval. This can only be interpreted by the receiver as a 0 pulse if no electron-hole pairs are generated with the pulse present. The probability that n = 0 electrons are emitted in a time interval is $P_r(0) = e^{-N}$ where the average number of electron-hole pairs(N).Thus for a given error probability $P_r(0)$, we can find the minimum energy E required at a specific wavelength.

12.Compare the performance of APD and PIN diode (Nov '08)

The avalanche photodiode (APD), is also reverse-biased. The difference with the PIN diode is that the absorption of a photon of incoming light may set off an electron-hole pair avalanche breakdown, creating up to 100 more electron-hole pairs. This feature gives the APD high sensitivity (much greater than the PIN diode).

13.Mention types of preamplifiers.

(a) Low impedance preamplifiers, (b) High impedance preamplifiers
(c) Transimpedance preamplifiers

14.What are the advantages of preamplifier? (May '15)

(a).low noise level, (b).high bandwidth, (c).high dynamic range, (d).high sensitivity, (e).high gain

15.What are the standard measurement techniques?

(a).Reference test methods, (b).Alternative test methods

16.Mention the different techniques used for measurement of fiber refractive profile

(a).Interferometric Method, (b).Near field scanning method, (c).Refractive near field method

17.Define effective cutoff wavelength.

The effective cutoff wavelength is defined as wavelength greater than the ratio between the total power to the launched higher order modes and fundamental mode power.

18.Mention the techniques used for determination of fiber numerical aperture.

(a) farfield angle from fiber using a scanning photodetector and a rotating stage
(b) farfield pattern by trigonometric fiber
(c)farfield pattern of NA measurement using a rotating stage.

19. List out the advantages of outer diameter measurement.(Nov'14)

(a). speed is large, (b). more accuracy, (c).faster diameter measurements, (d)good accuracy

20. What are the standard measurement techniques?

(i) Reference Test Method, (ii) Alternative Test Method

21.List the advantage of outer diameter measurement

1. Speed is large,2. more accuracy,3. faster diameter measurements,4. Good accuracy.

22.Define Extinction ratio.

It is defined as the ratio of the optical power in a 0 pulse to the power in a 1 pulse. Its effect is a power penalty in receiver sensitivity.

23.How is Internal Noise caused?

Internal Noise is caused by the spontaneous fluctuation of current or voltage in electric circuits.

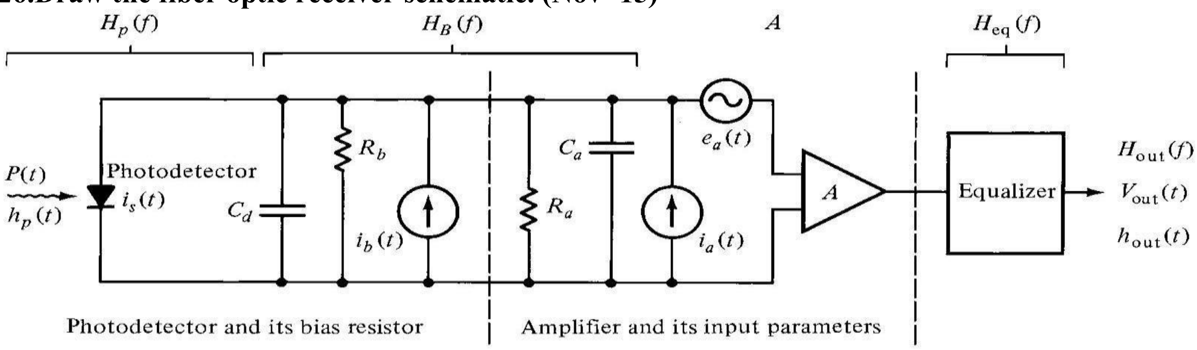
24. What is Intersymbol Interference?

ISI occurs from pulse spreading in the optical finer when a pulse is transmitted in a given time slot, most of the pulse energy will arrive in the corresponding time slot at receiver.

25. What is bit rate?

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

26.Draw the fiber optic receiver schematic. (Nov '15)



27.Mention few fiber diameter measurement techniques. (Nov '15)

(i) Inner diameter measurement (ii) Outer diameter measurement.

PART B

1. Explain the different types of Preamplifiers used in a receiver**.(Nov '13)**
2. Define the term Quantum limit and derive a suitable expression for Probability of Error with respect to receiver**.(May '13) (Nov '15)**
3. Explain the various methods used for Fiber attenuation measurements**.(Nov '13/'15) (May '15)**
4. Explain the Time domain Measurement method for fiber dispersion measurements with relevant expressions**.(May '12,May '14) (Nov '15) (May '15)**

5. Explain the Frequency domain Measurement method for fiber dispersion measurements with relevant expressions**.(Nov '12)**
6. Explain the measurement technique used in the case of

   (i) Numerical aperture**(Nov '14, May '14)** (ii) Refractive index profile**(Nov '14)**
7. Explain the measurement technique used in the case of

   (i) Fiber cut-off wave length (ii) Fiber diameter.
8. Discuss in detail about (a). interferometric methods (b). near field scanning method

   (c). refracted near field method.
9. Describe with a suitable diagram, the shadow method used for the on-line measurement of the outer diameter of optical fiber.
10. Draw the block diagram of fundamental optical receiver. Explain each block. **(Nov'14, May '14) (May '15)**

UNIT V- OPTICAL NETWORKS AND SYSTEM TRANSMISSION

PART A

1.**What are solitons and give its significance? (May '13, Nov '14, May '14) (May '15)**

The term "Soliton" refers to special kinds of waves that can propagate undistorted over long distances and remain after collisions with each other. John Scott Russell made the first recorded observation of a soliton in 1838,when he saw a peculiar type of wave generated by boats in narrow Scottish canals.In optical communication systems, solitons are very narrow, high-intensity optical pulses that retain their shape through the interaction of balancing pulse dispersion with the nonlinear properties of an optical fiber.The set of pulses that do not change in shape are called fundamental solitons, and those that undergo periodic shape changes are called higher-order solitons.

2.What are repeaters?

In optical communications the term repeater is used to describe a piece of equipment that receives an optical signal, converts that signal into an electrical one, regenerates it, and then retransmits an optical signal. Since such a device converts the optical signal into an electrical one, and then back to an optical signal, they are often known as Optical Electrical Optical(OEO) repeaters.

3.What is frequency chirping?

A **chirp** is a signal in which the frequency increases ('up-chirp') or decreases ('down-chirp') with time. It is commonly used in sonar and radar, but has other applications, such as in spread spectrum communications. In frequency chirping the rising edge of the pulse experiences a red shift in frequency(toward higher frequencies), whereas the trailing edge of the pulse experiences a blue shift in frequency(toward lower frequencies).

4.Why do we use NRZ coding scheme generally?

For a serial data stream, an on-off (or uni polar) signal represents a 1 by a pulse of current or light filling an entire bit period, whereas for a 0 no pulse is transmitted. These codes are simple to generate and decode, but they possess no inherent error-monitoring or correcting capabilities and they have no self-clocking (timing) features.

5.What are the system requirements in analyzing a point-to-point link?(AU-DEC'05)

The following key system requirements are needed in analyzing point-to-point link
a. The desired (or possible) transmission distance. (b) The data or channel
bandwidth c. The bit-error rate (BER)

6.Explain the principle of operation of fiber amplifier

The device absorbs energy supplied from an external source called the pump. The pump supplies energy to electrons in an active medium, which raises them to higher energy levels to produce a population inversion. An incoming signal photon will trigger these excited electrons to drop to lower levels through a stimulated emission process, thereby producing an amplified signal.

7.List out the benefits of SONET and PDH?(Nov '13) (May '15)

Synchronous optical networking (SONET) and **Synchronous Digital Hierarchy (SDH)**, are multiplexing protocols that transfer multiple digital bit streams using lasers or light-emitting diodes (LEDs) over the same optical fiber. The method was developed to replace the Plesiochronous Digital Hierarchy (PDH) system for transporting larger amounts of telephone calls and data traffic over the same fiber wire without synchronization problems.

8. What is SDH?

The basic format of an SDH signal allows it to carry many different services in its Virtual Container (VC) because it is bandwidth-flexible. Synchronous optical networking (SONET) and Synchronous

Digital Hierarchy (SDH), are multiplexing protocols that transfer multiple digital bit streams using lasers or light-emitting diodes (LEDs) over the same optical fiber.

9.Sate the concept of WDM. (Nov-2014)

In fiber-optic communications, **wavelength-division multiplexing** (**WDM**) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths (colours) of laser light to carry different signals. This allows for a multiplication in capacity, in addition to enabling bidirectional communications over one strand of fiber. This is a form of frequency division multiplexing (FDM) but is commonly called wavelength division multiplexing.

10. What is the significance of rise time budget? (Nov ’08, Apr ’08)

A rise time budget analysis is a convenient method for determining the dispersion limitation of an optical fiber link $t_{sys} = (t_{tx}^2 + t_{mod}^2 + t_{mat}^2 + t_{rx}^2)^{1/2}$

11. Compare doped fiber amplifiers and conventional repeaters. (Nov ’08)

Repeater	Fiber Amplifier
(i) Conversion of optical to electrical and amplify this signal and reconvert the electrical to optical (ii) Used in short distance (iii) Complex device (iv) Bandwidth utilization is less	(i) It directly amplify the optical signal without any conversion (ii) Used in long distance (iii) Device is les complex (iv) Bandwidth is utilized effectively

12. Distinguish fundamental and higher order solitions. (Nov ’07)

The family of pulses that do not change in shape are called fundamental solitons, and those that undergo periodic shape changes are called higher-order solitons. In either case, attenuation in the fiber will eventually decrease the soliton energy. Since this weakens the nonlinear interaction needed to counteract GVD, periodically spaced optical amplifiers are required in a soliton link to restore the pulse energy.

13. What is EDFA? (May ’08)

An Erbium Doped Fiber Amplifier (EDFA) consists of a piece of fiber of length L, whose core is uniformly doped with Erbium ions. Such ions can be thought of as simple two- level systems, i.e., they can have only two energy states:1) a fundamental state and 2) an excited state.

14. Define Modal Noise. (May ’ 07)

Noise generated in an optical fiber system by the combination of mode-dependent optical losses and fluctuation in the distribution of optical energy among the guided modes or in the relative phases of the guided modes.

15.What are the three common topologies used in fiber optic networks?

a) Linear Bus b) Ring c) Star

16.What is DWDM?

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

17..What are the types of broadcast and select network?

a) Single hop networks
b) Multihop networks

18.Define Kerr effect.

Nonlinearity produces a carrier induced phase modulation of the propagating signal which is called Kerr effect.

19. Define the basic signal rate of SONET.

STS-1={(90 bytes/row) x (9 rows/frame) x(8 bits/byte)} / (125μs/frame) = 51.84Mbps

20.Distinguish SONET and SDH. (Nov ’15)

SONET	SDH
(i) Synchronous Optical NETwork (ii) Used in North America (iii) Basic Signal rate:51.84Mbps (iv) 9 Rows 90 Columns	(i) Synchronous Digital Hierarchy (ii) Rest of the world (iii)Basic Signal rate:155.52Mbps (iv)9 Rows 270 Columns

21.What is optical CDMA? (Nov ’15)

An OCDMA system being a broadcast system sinks receive all source signals – as is normal in the case of CDMA. The advantage of this scheme is self-evident: it doesn‟t require any central control.

22.How the speckle pattern can form?

The speckle patterns are formed by the interference of the modes from a coherent source when the coherence time of the source is greater than the intermodal dispersion time within the fiber.

23.Give the important features of time slotted optical TDM network.
1. to provide backbone to interconnect high speed networks
2. to transfer quickly very large data bocks

24. What is called higher order solitons?
The family of pulses that undergo periodic shape changes are higher order solitons.

25. Define fundamental solitons. (May '13)
The family of pulses that do not change in shape are called fundamental solitons.

PART- B

1. Explain the SONET frame structures and SONET rings with neat diagrams.(**Nov '13, May '14) (Nov '15)**
2. Write short notes on SDH networks.
3. Explain the principles of WDM Networks. **(May '15)**
4. Explain the EDFA configuration in detail.
5. Explain the principle and operation of an optical amplifier.
6. Describe Non linear optical effects in detail. **(May '15)**
7. Write notes on Solitons**. (Nov '13)**
8. Explain the following requirements for the design of an optically amplified WDM link:
   (i) Link Band width.(**Nov '13)**
   (ii) Optical power requirements for a specific BER. **(Nov-2013)**
9. Explain the architecture of SONET and discuss nonlinear effects on Network performance **(Nov'11)**
10. Write short notes on
    (i) Wavelength routed networks
    (ii) Optical CDMA **(Nov '11)**
11. Explain the SA/SA protocol and modified S/SA protocol of Broadcast and select networks. **(May '13)**
12. Write detail notes on CDMA and its applications.(**May '13)**
13. Discuss the following
    (i) The performance improvement of WDM and EDFA systems. **(Nov '15)**
    (ii) Ultra high capacity networks. **(Nov '14) (May '15)**
14. With suitable example explain the conditions and constraints in the formulation and solution of routing and wavelength assignment problem in an optimal way.**(May '14).**