

Q1) a. Define (with Formula): Critical Angle, Refractive Index, Total Internal Reflection (TIR)

1. Critical Angle (θ_c):

Definition: The specific angle of incidence in a denser medium for which the angle of refraction in the less dense medium is exactly 90° .

Formula: $\theta_c = \sin^{-1}(n_2 / n_1)$

(Where n_1 is the refractive index of the core, and n_2 is the refractive index of the cladding).

2. Refractive Index (n):

Definition: A dimensionless number that describes how fast light travels through a specific material compared to the speed of light in a vacuum.

Formula: $n = c / v$

(Where c is the speed of light in a vacuum, and v is the speed of light in the medium).

3. Total Internal Reflection (TIR):

Definition: The phenomenon that occurs when propagating light strikes a medium boundary at an angle larger than a particular critical angle with respect to the normal to the surface, causing the light to be completely reflected back into the denser medium.

Formula/Condition: $\theta_i > \theta_c$ (and $n_1 > n_2$)

(Where θ_i is the incident angle and θ_c is the critical angle).

Q1) b. Select correct answer:

1. Optical communication primarily uses _____ to transmit information.

Answer: C. Light waves

2. The principle used in optical fiber communication is _____.

Answer: B. Total internal reflection

3. The process of converting optical signals back into electrical signals is done by _____.

Answer: C. Photo-detector

4. The main cause of signal loss in optical fiber is _____.

Answer: B. Attenuation and dispersion

5. The term bit rate in optical communication refers to _____.

Answer: B. Number of bits transmitted per second

Q2) An optical Fiber cable with core refractive index 3.55 and cladding refractive index of 3.45 is to be used to transmit a stream of data.

1. If the incident angle is 66° , will this result in Total Internal Reflection?

Answer: First, calculate the critical angle (θ_c):

$$\theta_c = \sin^{-1}(n_2 / n_1)$$

$$\theta_c = \sin^{-1}(3.45 / 3.55) = \sin^{-1}(0.9718) \approx 76.36^\circ$$

Since the incident angle (66°) is less than the critical angle (76.36°), Total Internal Reflection (TIR) will NOT occur.

2. If not, how you can make it possible?

Answer: To make TIR possible, the incident angle must be increased so that it is greater than the critical angle (i.e., incident angle $> 76.36^\circ$).

3. Calculate the Numerical Aperture (NA), Acceptance angle (θ_a), and relative refraction index (Δ):

- Numerical Aperture (NA):

$$NA = \sqrt{n_1^2 - n_2^2}$$

$$NA = \sqrt{3.55^2 - 3.45^2} = \sqrt{12.6025 - 11.9025} = \sqrt{0.7} \approx 0.8366$$

- Acceptance Angle (θ_a):

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

$$\theta_a = \sin^{-1}(0.8366) \approx 56.78^\circ$$

- Relative Refractive Index (Δ):

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

$$\Delta = (3.55 - 3.45) / 3.55 = 0.1 / 3.55 \approx 0.0281 \text{ (or } 2.81\%)$$

Q3) In optical communication system, an optical fiber has average loss of 0.25 dB/Km is used.

Attenuation formula: $\alpha = (10 / L) * \log_{10}(P_{in} / P_{out})$

Rearranging for Length (L): $L = (10 / \alpha) * \log_{10}(P_{in} / P_{out})$

Compute the length at which the power reduced by:

(Note: "Reduced by" means we calculate based on the remaining power).

a. 30% of transmitted power

Answer: If power is reduced by 30%, the remaining power (P_{out}) is 70% of P_{in} .

$P_{out} = 0.70 * P_{in}$ (Therefore, $P_{in} / P_{out} = 1 / 0.70 \approx 1.428$)

$$L = (10 / 0.25) * \log_{10}(1 / 0.70)$$

$$L = 40 * \log_{10}(1.428)$$

$$L \approx 40 * 0.1549 \approx 6.19 \text{ km}$$

b. 65% of transmitted power

Answer: If power is reduced by 65%, the remaining power (P_{out}) is 35% of P_{in} .

$P_{out} = 0.35 * P_{in}$ (Therefore, $P_{in} / P_{out} = 1 / 0.35 \approx 2.857$)

$$L = (10 / 0.25) * \log_{10}(1 / 0.35)$$

$$L = 40 * \log_{10}(2.857)$$

$$L \approx 40 * 0.4559 \approx 18.23 \text{ km}$$