

Optical communication - S1-E1 -a

Q1) Why – Give reasons for 5 of following:

1. Satellite communication is point to multi-point, while optical communication is point to point.

Answer: Satellites broadcast signals over a wide footprint covering a large geographic area, allowing multiple receivers to pick up the same signal simultaneously (point-to-multipoint). In contrast, optical fibers are physical cables that connect specific transmitter and receiver nodes directly, guiding the light exclusively between those two distinct endpoints (point-to-point).

2. Optical communication is high security system.

Answer: Optical fibers do not emit electromagnetic fields, making data interception (tapping) almost impossible without physically cutting or sharply bending the cable. Any such attempt causes a sudden signal drop, immediately alerting the system of a breach.

3. Optical communication is resistive to interference.

Answer: Optical fibers transmit data using light waves (photons) through glass rather than electrical currents (electrons) through copper. Since glass is a dielectric insulator, fibers are completely immune to Electromagnetic Interference (EMI), Radio Frequency Interference (RFI), and lightning strikes.

4. For use in communications and some other applications, the optical fiber is provided with a cladding.

Answer: The cladding has a lower refractive index than the core, which is the essential condition to keep the light confined inside the core. It also provides mechanical protection and prevents surface contamination that could cause signal leakage.

5. Optical fiber requires a light source for launching light into the fiber at its input end and a photo detector to receive light at its output end.

Answer: A light source (like a Laser or LED) is needed to convert electrical signals into optical signals to be sent through the fiber. A photo detector is needed at the receiving end to reverse the process, converting light back into electrical signals.

6. Core has refractive index greater than of cladding.

Answer: This is the fundamental physical condition (based on Snell's Law) for Total Internal Reflection to occur. If the core does not have a higher refractive index, the light will escape into the cladding instead of reflecting inside the cable.

7. Total Internal Reflection (TIR) principle is used in propagation of light through optical fiber cable.

Answer: This principle is the exact mechanism that allows light to continuously reflect inside the core walls without escaping. This enables the optical signal to travel long distances smoothly and efficiently.

Q2) An optical Fiber cable with core refractive index 3.7 and cladding refractive index of 3.5 is to be used to transmit a stream of data.

1. If the incident angle is 68°, will this result in Total Internal Reflection (TIR)?

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

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

$$\theta_c = \sin^{-1}(3.5 / 3.7) = \sin^{-1}(0.9459) \approx 71.07^\circ$$

Since the incident angle (68°) is less than the critical angle (71.07°), 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 > 71.07°).

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

- Numerical Aperture (NA):

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

$$NA = \sqrt{3.7^2 - 3.5^2} = \sqrt{13.69 - 12.25} = \sqrt{1.44} = 1.2$$

- Acceptance Angle (θ_a):

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

$$\theta_a = \sin^{-1}(1.2)$$

(Note: Since the NA is greater than 1, mathematically $\sin^{-1}$ is undefined. Physically, this means the fiber has a maximum acceptance angle of 90°, accepting light from all angles in air).

- Relative Refractive Index (Δ):

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

$$\Delta = (3.7 - 3.5) / 3.7 = 0.2 / 3.7 \approx 0.054 \text{ (or 5.4\%)}$$

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

(Note: Assuming the unit is dB/km).

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 becomes:

a. 55% of transmitted power

Answer: $P_{out} = 0.55 * P_{in}$ (Therefore, $P_{in} / P_{out} = 1 / 0.55$)

$$L = (10 / 0.25) * \log_{10}(1 / 0.55)$$

$$L = 40 * \log_{10}(1.818)$$

$$L \approx 40 * 0.2596 \approx 10.38 \text{ km}$$

b. 20% of transmitted power

Answer: $P_{out} = 0.20 * P_{in}$ (Therefore, $P_{in} / P_{out} = 1 / 0.20 = 5$)

$$L = (10 / 0.25) * \log_{10}(5)$$

$$L = 40 * 0.69897 \approx 27.96 \text{ km}$$