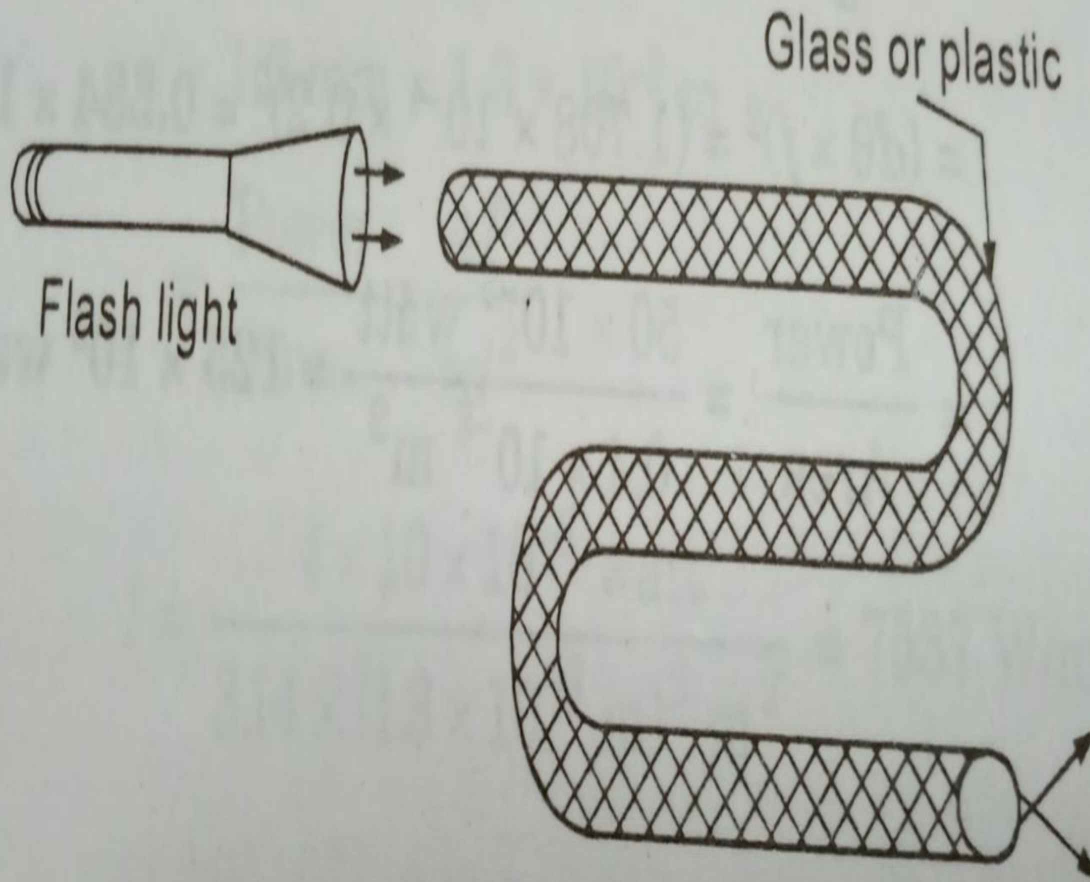
FIBRE OPTICS

Fibre optics:-

- Fibre optics deals with the transmission of light through fibres of glass, plastic or other transparent materials and works on the principle of total internal reflection(TIR).

OPTICAL FIBRES:-

- Optical fibres are glass or plastic pipes, as thin as human hair, that guide light waves through them and work on the principle of TIR.
- When light enters into the optical fibre, it undergoes successive TIRs from side walls and travels down the length of the fibre along a zig-zag path as shown in figure.


Glass or plastic
Flash light

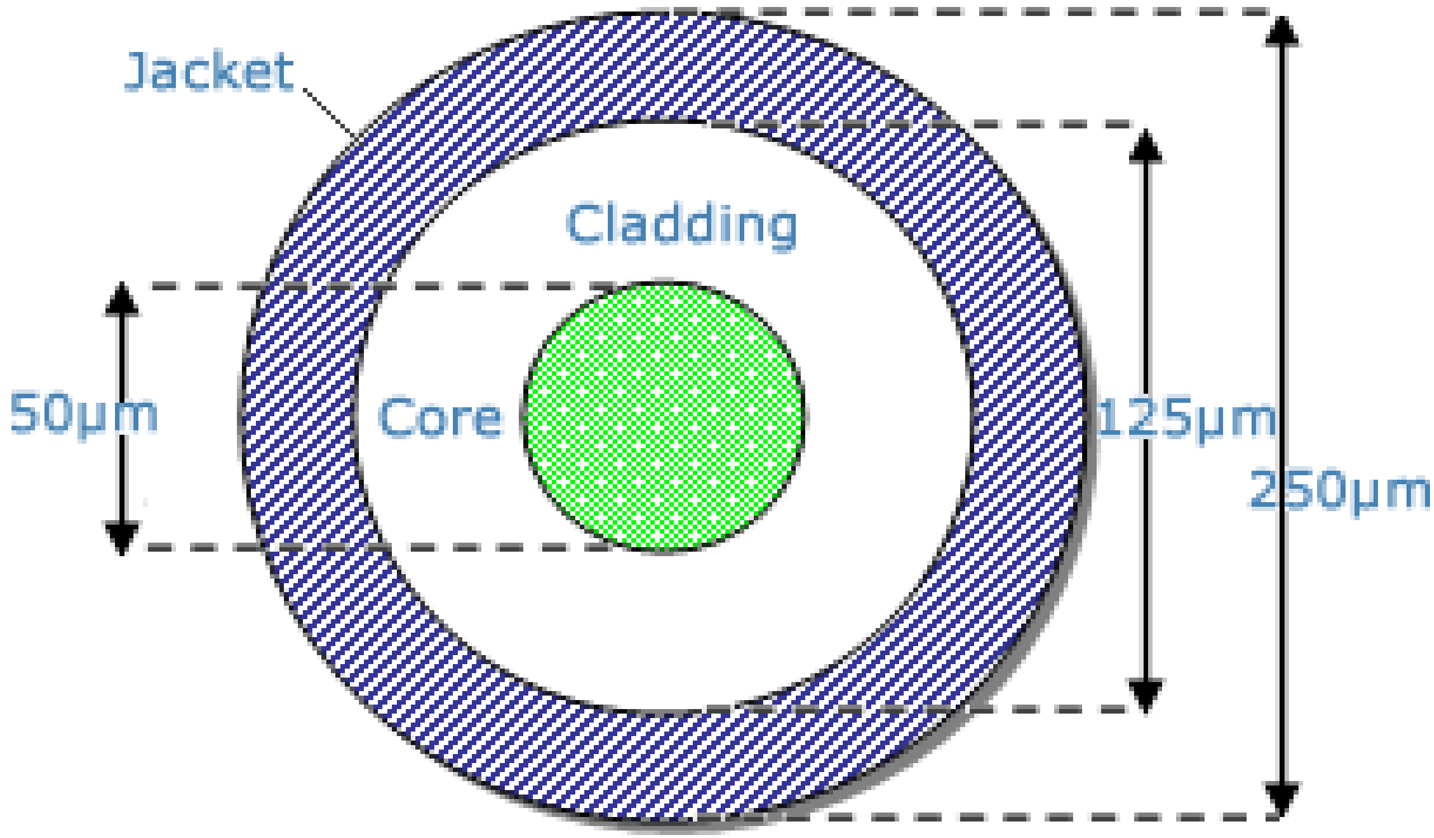
- Optical fibre consist of essentially 3 regions
- The central region is known as **core.**
- The middle region is called the **cladding.**
- The outer region is a **protective sheath.**

- The cladding keeps the light waves within the core and provides strength to the core.
- The outer protective sheath protects the cladding and core from abrasions, contamination and moisture.

- Optical fibres are fabricated from from glass or plastic which are transparent to optical frequencies.with these materials 3 major types of fibres are made:-

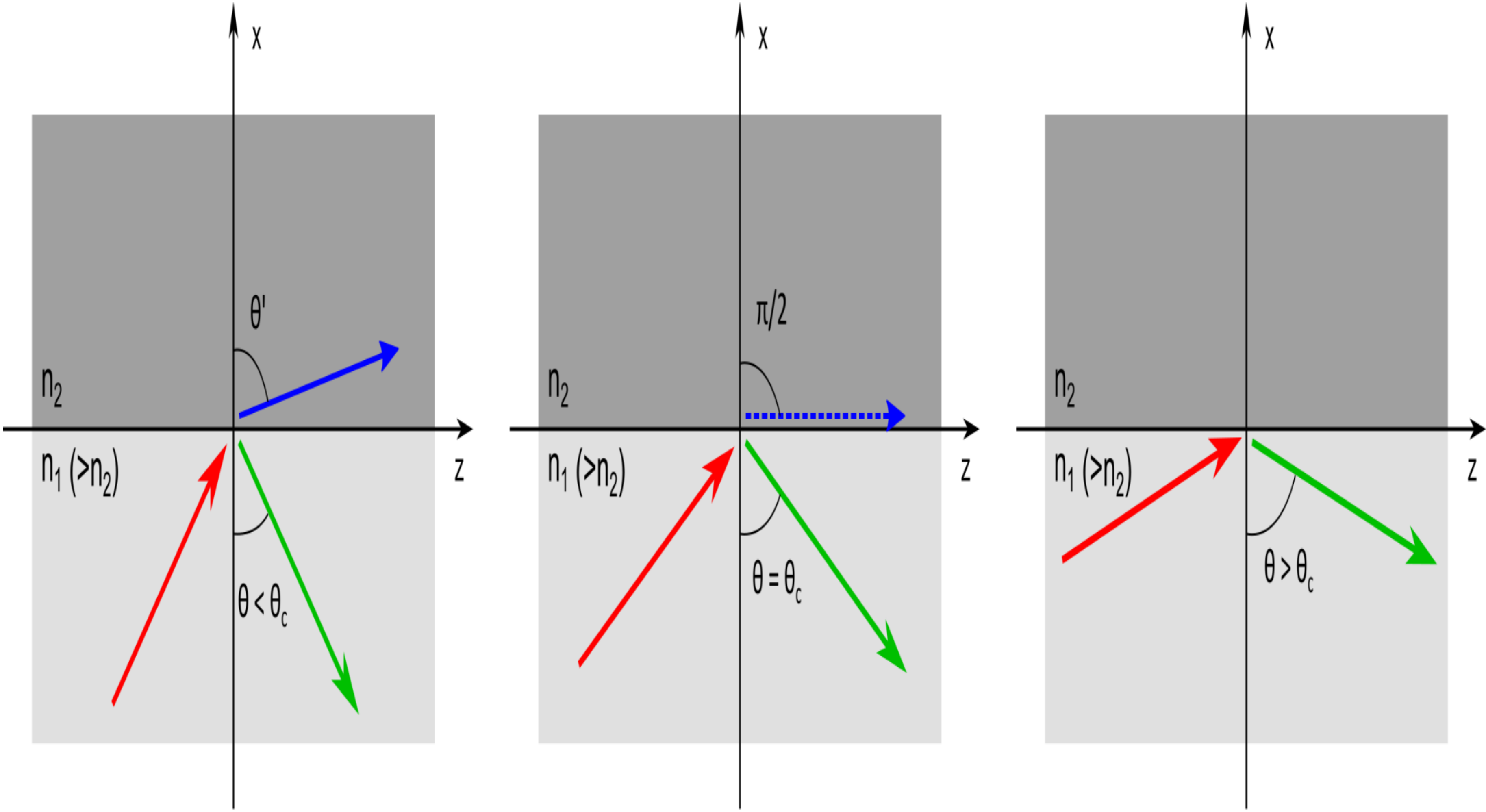
1. Plastic core with plastic cladding.
2. Glass core with plastic cladding.
3. Glass core with glass cladding.

Cross sectional view of optical-fibre



TOTAL INTERNAL REFLETION:-

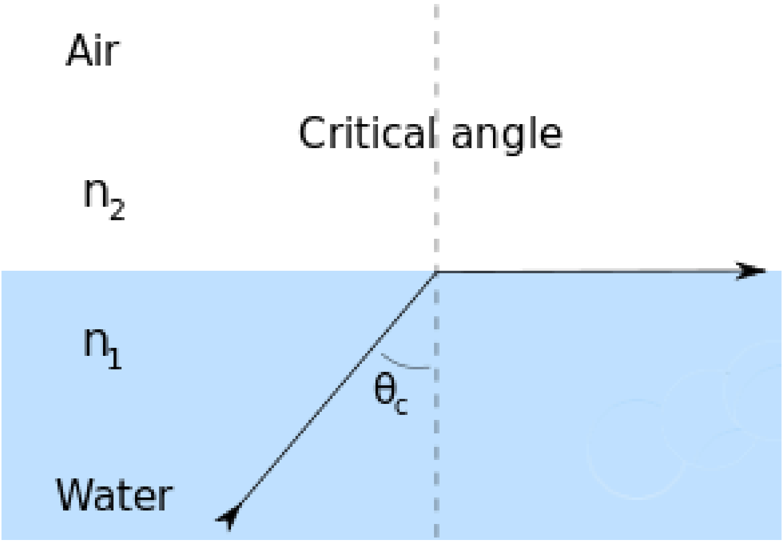
- When light travels from a medium with a higher refractive index to a medium with a lower refractive index and it strikes the boundary at more than the critical angle, all light will be refelcted back to the incident medium meaning it will not penetrate the second medium.
- This phenomenon is known as total internal reflection.
- Total internal reflection keeps light inside an optical fibre.



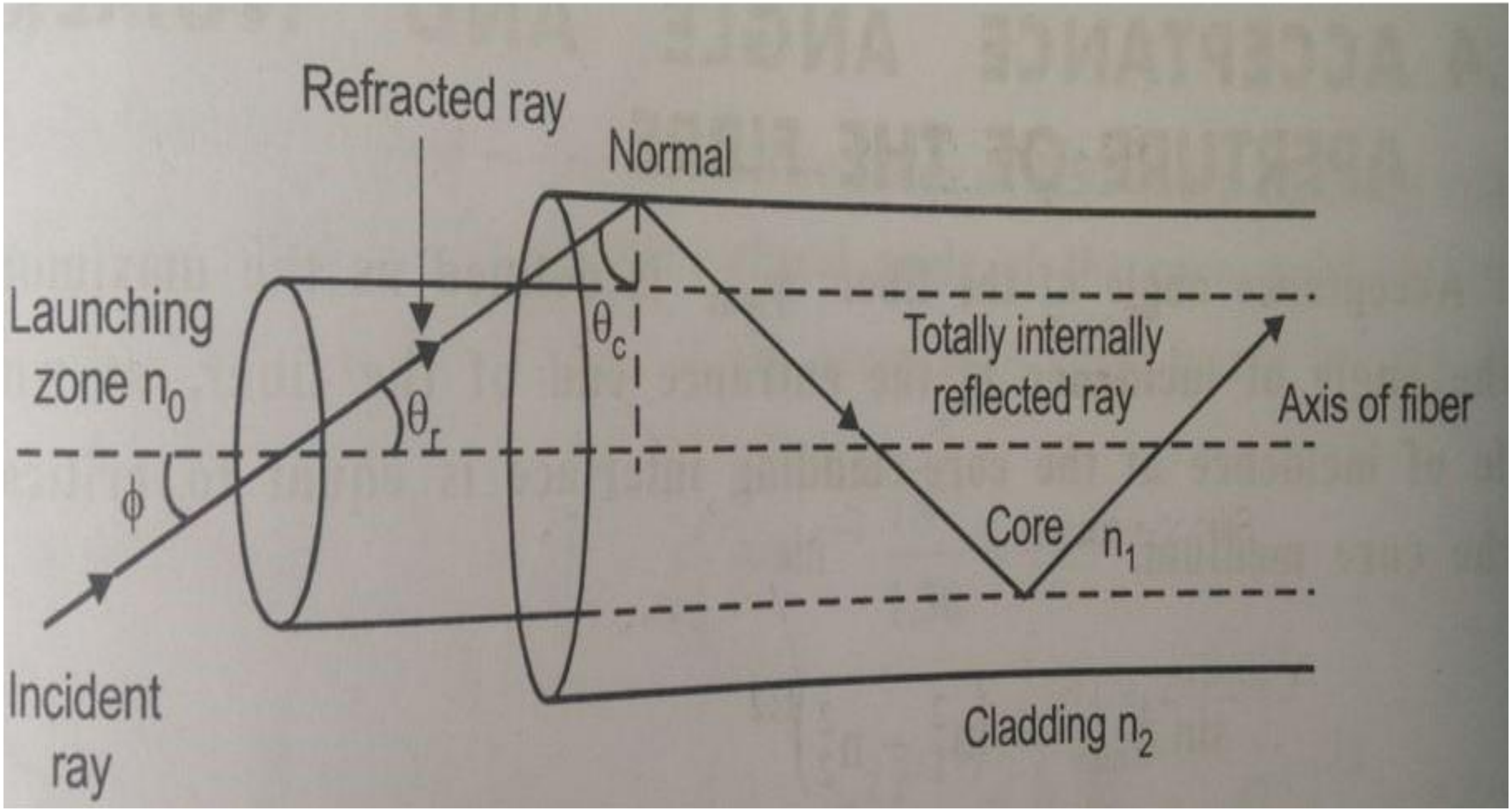
(a) partial reflection (b) critical angle (c) total internal reflection

CRITICAL ANGLE:-

- The critical angle is the angle of incidence where the angle of refraction is 90^{o} .
- The light must travel from an optically more dense medium to an optically less dense medium.



Propagation of Light through Optical Fibers



- The end at which the light enters the fibre is called the launching end.
- Let n_1 is refractive index of core and n_2 is refractive index of of cladding ($n_2<n_1$).
- Refractive index of outside medium from which the light is launched into the fibre is n_0.
- Let a light ray enter the fibre at an angleθ_i and refracted ray make an angle θ_r with the axis of fibre and strikes the core-cladding interface at an angle ϕ.

...of light in an optical fibre.

If $\phi > \theta_c$ (critical angle), the ray undergoes total internal reflection at the interface. As long as the angle $\phi > \theta_c$, the light remains within the fibre.

Applying Snell's Law to the launching face of the fibre, we get

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_1}{n_0} \qquad \text{...(2)}$$

Now largest value of θ_i occurs when $\phi = \phi_c$

From ΔABC we have

$$\sin\theta_r = \sin(90° - \phi) = \cos\phi \qquad \text{...(3)}$$

From eqn. (2)

$$\sin\theta_i = \sin\theta_r \frac{n_1}{n_0}$$

$$\sin\theta_i = \frac{n_1}{n_0}\cos\phi \qquad \text{...(4)}$$

when $\phi = \phi_c$, $\theta_i = \theta_{max}$

$$\sin\theta_{max} = \frac{n_1}{n_0}\cos\phi_c \qquad \text{...(5)}$$

But $\sin\phi_c = \dfrac{n_2}{n_1}$

$$\therefore \quad \cos\phi_c = \frac{\sqrt{n_1^2 - n_2^2}}{n_1} \qquad \text{...(6)}$$

Substituting the expression (6) into (5), we get

$$\boxed{\sin\theta_{max} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}} \qquad \text{...(7)}$$

If $(n_1^2 - n_2^2) \geq n_0^2$, then for all values of θ_i, total internal reflection will occur.

- Assuming $n_0=1$ the maxiumum value of $\sin\theta_i$ for a ray to be guided is given by
- $\sin \theta_m = \sqrt{n_1^{\,2} - n_2^{\,2}}$ or
- $\theta_m = \sin^{-1} \left(\sqrt{n_1^{\,2} - n_2^{\,2}} \right)$
- The angle θ_m is called the acceptance angle of the fibre.

- Acceptance angle may be defined as the maxiumum angle that a light ray can have relative to the axis of the fibre and propagates down the fibre.
- The light rays contained within the cone having a full angle $2\theta_m$ are accepted and transmitted along the fibre.
- this cone is known as acceptance cone.

Fibre characteristics and classification:-

- The characteristics of light transmission through a glass fibre depend on many factors such as:-

1. The composition of fibre.
2. The amount and type of light introduced into the fibre.
3. The diameter and length of fibre.

- The composition of fibre determines the refractive index.
- By the process of doping other materials are introduced into the material that alter its index number.
- This process produces a single fibre with a core index n_1 and cladding n_2.

- Another characteristics of the fibre which depends on its size is its mode of operation.
- Depending upon the mode of operation optical fibres are classified into 2 categories such as:-

1. Single mode fibre (only one mode)
2. Multi mode fibre(many mode)

Index profile:-

- An index profile is a plot of refractive index drawn on the horizontal axis versus the distance from the core axis drawn on the horizontal axis.
- The index profile of a multimode fibre can be:-

1. Step index
2. Graded index

- The index profile of a single mode fibre is usually a step index type.
- In the step index fibre the refractive index is constant through out the core.
- In such a fibre the refractive index profile abruptly changes at the junction of the core and cladding.
- Because of this abrupt change they are called step index fibres.

- In the graded index fibre, the highest index is at the centre and decreases gradually until it reaches the index number of the cladding, i.e near the surface.

- Basing upon the profile index optical fibres are 3 types:-

1. Multi mode step index fibre(MMSIF).
2. Multi mode grade index fibre(MMGIF).
3. Single mode step index fibre(SMSIF).

5.22 ATTENUATION CONSTANT

The attenuation or transmission loss of optical fibers has proved to be one of the most important factors in bringing about their wide acceptance in telecommunications. In practice, we measure attenuation (A) in dB/km, but for some calculations we use the attenuation consatnt

(α) in $\frac{1}{\text{km}}$. Let's study the relationship between them :

In general, the attenuation is defined by the formula

$$\text{Loss} = \frac{P_{out}}{P_{in}} \qquad ...(19)$$

where power (P_{out} and P_{in}) is measured in watts. This formula implies that attenuation measured in km^{-1} is given by :

$$A\left(\frac{1}{\text{km}}\right) = [P_{out}/P_{in}]/L \text{ (km)} \qquad ...(20)$$

and the input/output power relationship is governed by the following formula :

...(21)

$$P_{out} = P_{in}\ (AL)$$

This formula shows that output power is proportional to attenuation A (km^{-1}). Usually, as we have seen, attenuation is measured in dB/km. To do so, the following formulas were introduced :

$$\text{loss (dB)} = -\ 10 \log (P_{out}/P_{in}) \quad ...(22)$$

$$A\ (\text{dB/km}) = [-\ 10 \log (P_{out}/P_{in})]/L \quad ...(23)$$

This is the most common definition of attenuation.

Another quantity describing the loss property of an optical fiber is the attenuation constant (α). This constant shows that magnitudes of electric and magnetic fields in a lossy dielectric degrade at an exponential rate. In order to develop this idea, we arrive at the following expression for power attenuation along the fiber.

$$dp/dz = -\ \alpha P \quad ...(24)$$

wher α is the (power) attenuation constant measured in 1/km.

Let's consider a fiber whose length is L (km) and P_{out} and P_{in} are the output input light power, respectively, of this fiber. Then

$$\int_{P_{in}}^{P_{out}} \frac{dP}{P} = -\ \alpha \int_{0}^{L} dz \quad ...(25)$$

which, after intergration yields

$$P_{out} = P_{in}\ e^{-\alpha L} \quad ...(26)$$

Hence, *output power depoends, exponentially, on the attenuation constant measured in 1/km.*

If we express the attenuation constant, α is dB/km, as

$$\alpha\ (\text{dB/km}) = [-\ 10 \log (P_{out}/P_{in})]/L \quad ...(27)$$

Put the value of P_{out} from eq. (8) into eq. (5), we get

$$A\ (\text{dB/km}) = \left[-10 \log\left(\frac{P_{in} e^{-\alpha L}}{P_{in}}\right)\right]/L$$

$$= 10\ \alpha \log_e$$

$$A\ (\text{dB/km}) = 4.34\ \alpha\ (1/\text{km}) \quad ...(28)$$

Thus for $A = \alpha = 0.2$ dB/km we can compute $\alpha = 0.23 \times 0.2 = 0.046 \dfrac{1}{\text{km}}$.

Now the question is ; which quantity—attenuation (A) or attenuation constant (α) is used in calculating the losses. It follows from formulae (27) and (34) that

$$\alpha\left(\frac{1}{\text{km}}\right) = -\frac{1}{L(\text{km})}\ \ln\left[A\,(1/\text{km})\,L\,(\text{km})\right] \qquad ...(29)$$

or
$$A\,(1/\text{km}) = [1/L\,(\text{km})]\ e^{[-\alpha\,(1/\text{km})\,L\,(\text{km})]} \qquad ...(30)$$

Hence, *when using attenuation in dB/km, either A or α can be used, so eq.* (29) *and* (33) *are therefore identical. However, when measuring attenuation in 1/km, distinguish between attenuation and attenuation constant and use either eq.* (26) (*for attenuation*) *or eq.* (35) (*for atenuation constant*).

ATTENUATION:-

- Attenuation is the reduction of signal strength or light power over the length of the light carrying medium.
- Attenuation is mainly a result of light absorption, scattering and band losses.
- Optical fibre offers superior performance over other transmission media because it combines high bandwidth with low attenuation.

ADVANTAGES:-

1. Cheaper
2. Safety
3. Small size and light weight
4. Wider band width
5. Low losses
6. Confidential information cannot be routed to unwanted receivers.
7. Long life.

Disadvantages:-

1. Limited application
2. Nuclear radiation
3. Low power devices
4. Distance :-because of the low power sources the distance between repeatervamplifiers must be relatively short for the high data rates demanded in some system.
5. Limited way for light source modulation.
6. Fragility

USE OF OPTICAL FIBRE:-

1. Used in the field of communications as information channel or transmission medium.
2. Also used in telephone, cableTV, videophone, multi media etc.
3. In military mobiles such as air craft , ships, tanks etc.
4. CCTV links for traffic controls, security etc.
5. In medical.

THANK YOU