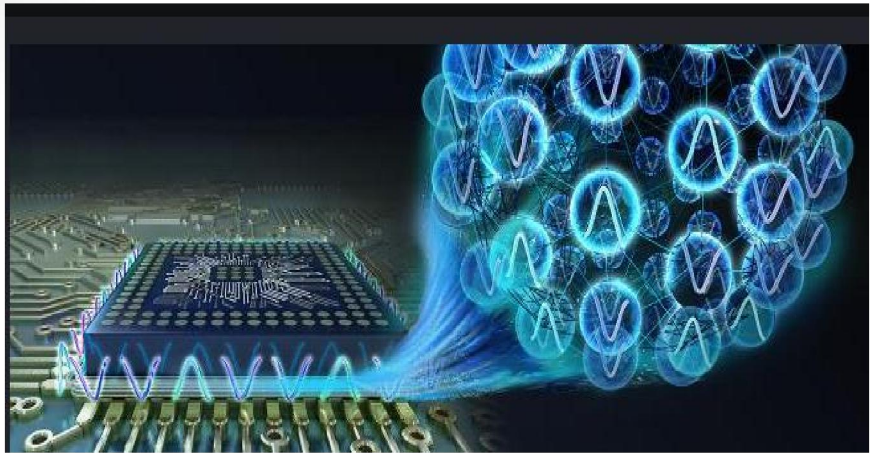
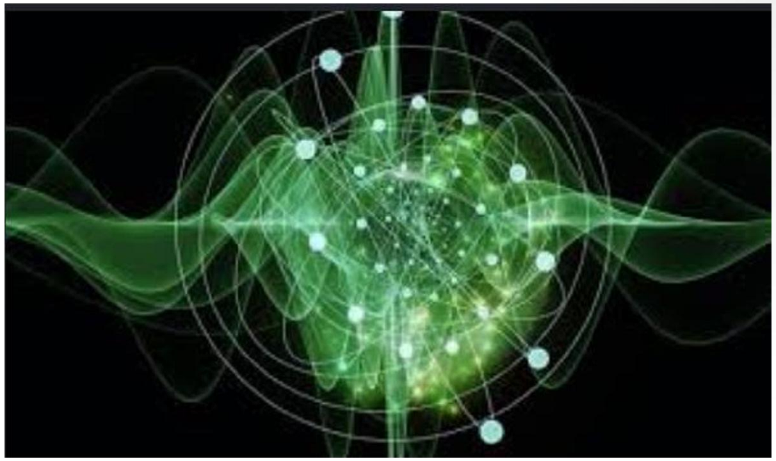
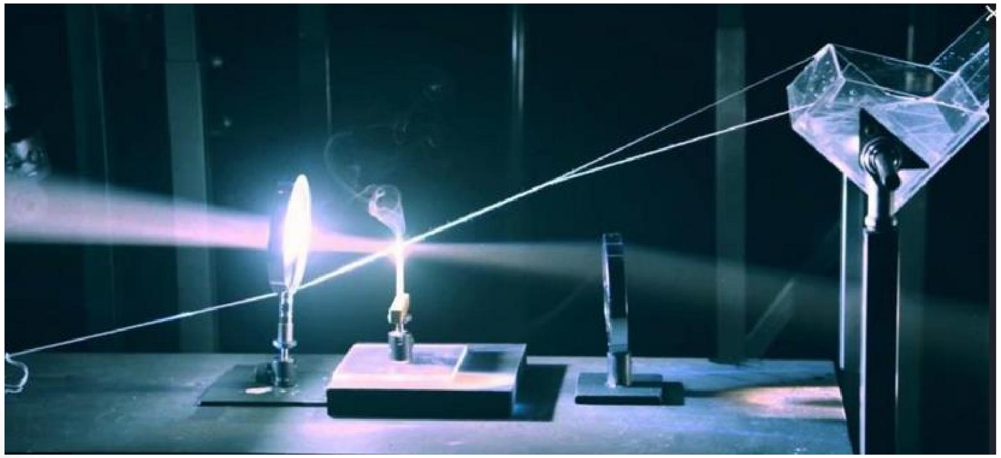
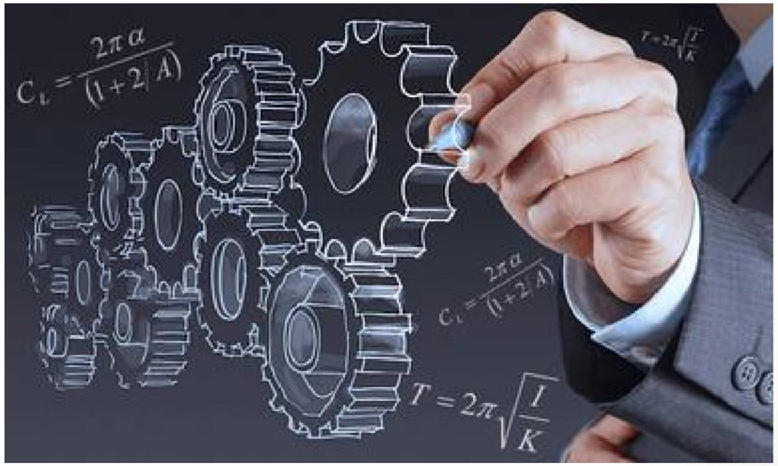




Engineering Physics (PHY109)





Course overview

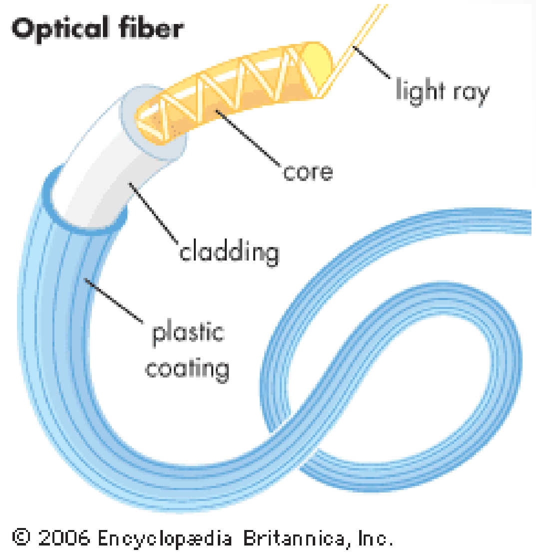
L: 3 T:1 P:0 Credits:4

- **Unit 1: Electromagnetic theory**
- **Unit 2: Lasers and applications**
- **Unit 3: Fiber optics**
- **Unit 4: Quantum mechanics**
- **Unit 5: Waves**
- **Unit 6: Solid state physics**

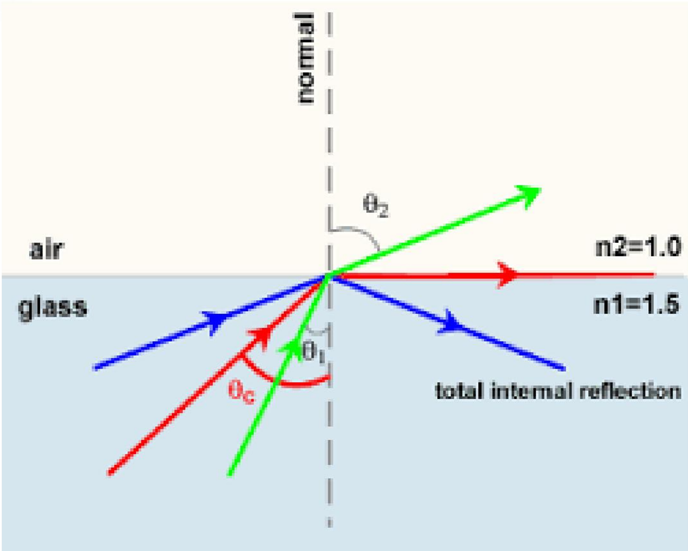
Unit-3: Fiber optics

Unit-3: Fiber optics

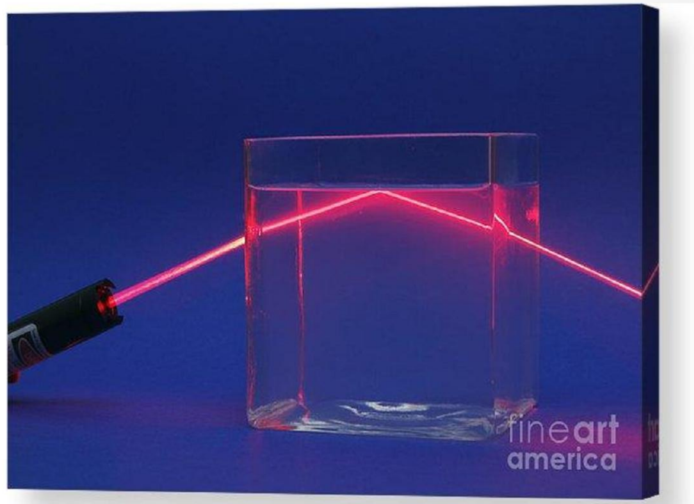
- Introduction to optical fiber
- Optical fiber as a dielectric wave guide
- Total internal reflection
- Acceptance angle & Numerical aperture
- Relative refractive index
- V-number
- Step index and graded index fibers
- Losses associated with optical fibers
- Application of optical fibers

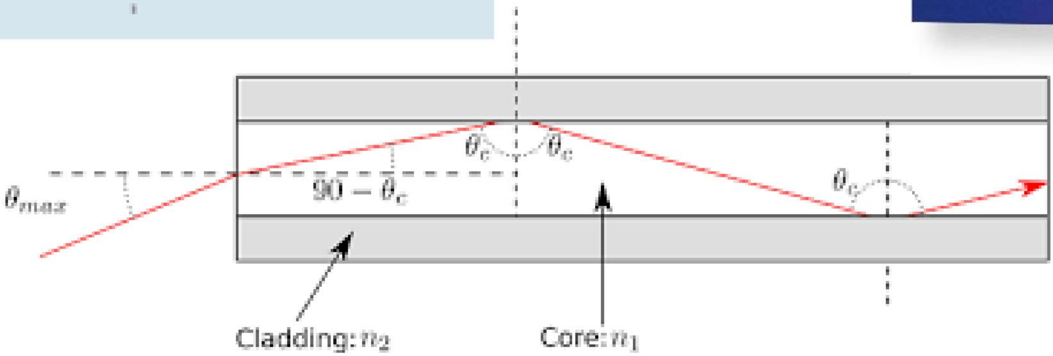


Refraction→TIR

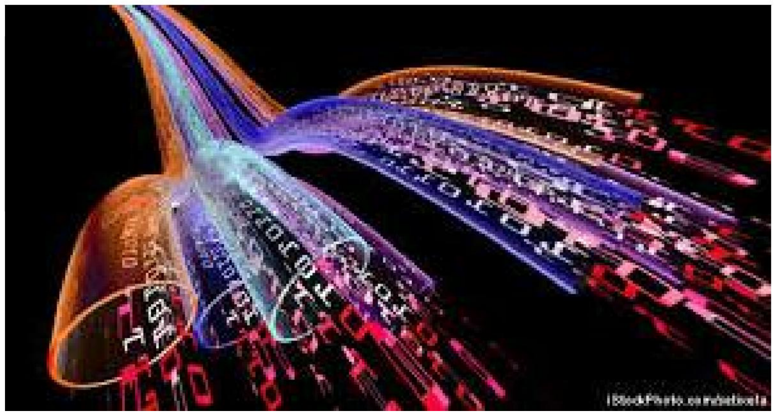


Total internal reflection





High speed data transfer

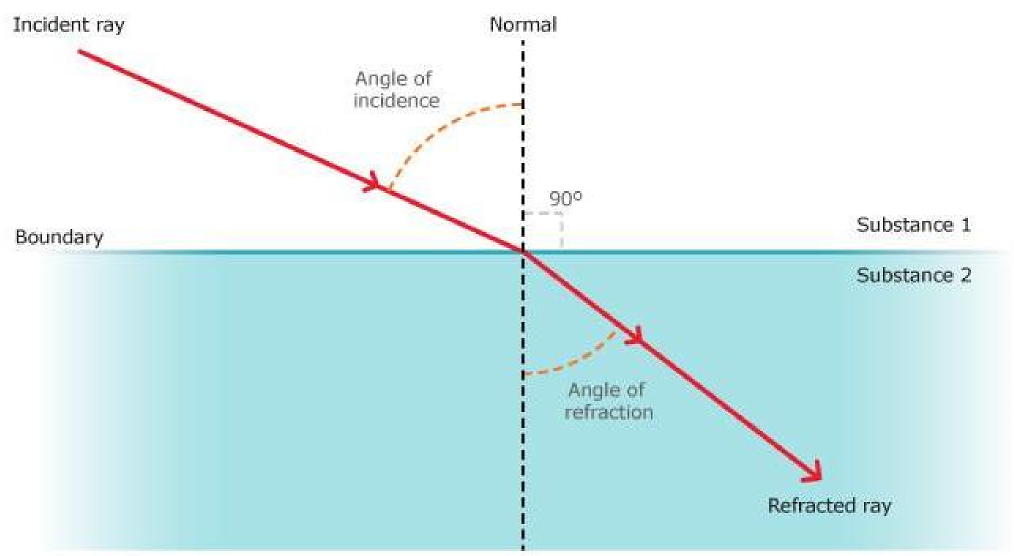


CO3: discover the concepts of physics in understanding fiber optics

Key phenomena

- Refraction: phenomenon of light, being deflected in passing through the interface between one medium and another or through a medium of varying density

Refraction of light



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Refractive indices

- In optics, the *refractive index* or *index* of *refraction* of a material is a dimensionless number that describes how light propagates through that medium. It is defined as

Where,

c is the speed of light in vacuum and

v is the phase velocity of light in the medium.

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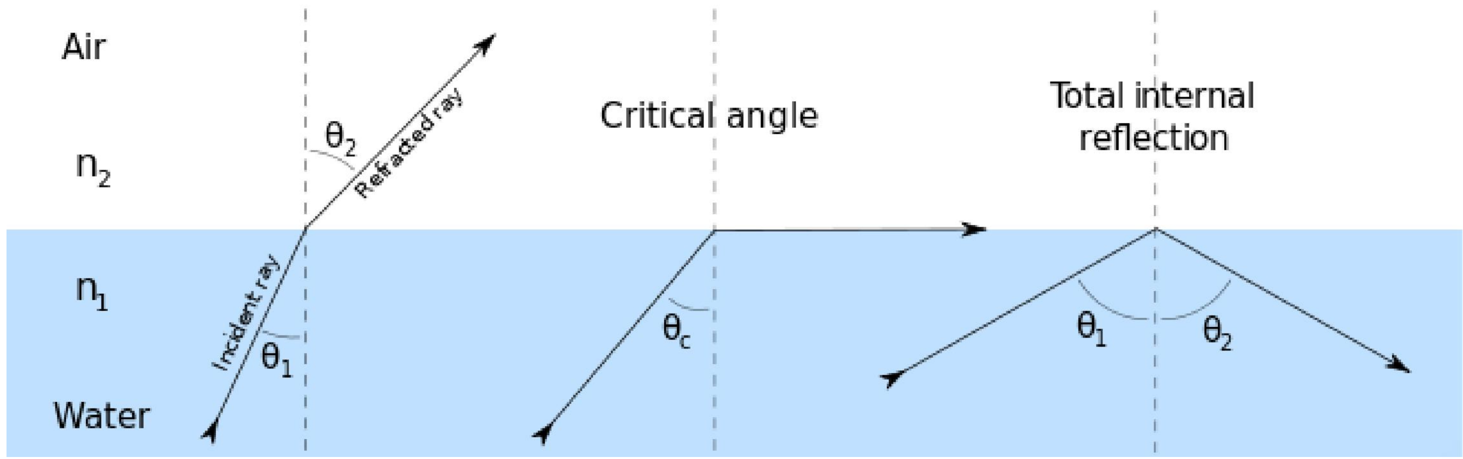
Critical angle

- The incident angle at which the angle of refraction is equal to 90’ is called critical angle
- Glass core+plastic cladding has critical angle of 82’
- Which means light rays having incident angle more than 82 will get internal reflection



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Introduction

- Many years, radiowaves and microwaves were being used as a carrier waves in communication systems

- However, energy of light waves gets dissipated in open atmosphere, hence cannot travel long distance

- Hence, guiding channel is required (just like a metal wire is required to guide electrical current)

- Firstly, in 1960 first ever fibre optical telecommunication was conceptualized with the help of laser

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Introduction

- Hence the purpose is solved by optical fiber
- Def: a very thin glass or plastic cable designed to guide light waves along the length of the fiber
- As long as the refractive index of the fiber is greater than that of its surrounding medium, the light will undergo total internal reflections to travel at the opposite end of the fiber

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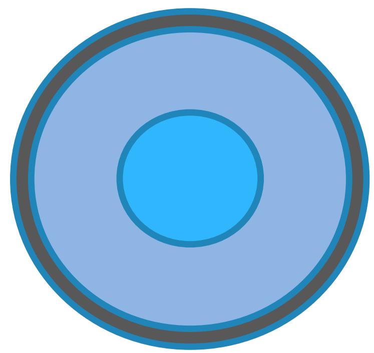
Introduction

- Uses glass, plastic, threads or fibres to transmit data

Core (n_1) [glass]

Cladding (n_2) [optical material]

Sheath [plastic protecting material]



$n_1 > n_2$ (total internal reflection)

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Dielectric waveguide

- An optical fibre is a dielectric waveguide with a **very high bandwidth**
- A **Waveguide** that consists of a **Dielectric** material surrounded by another **dielectric** material, such as air, glass, or plastic, with a lower refractive index
- It guides electromagnetic waves in an optical spectrum, the same way as microwaves are guided by rectangular or cylindrical metallic waveguides
- An optical fibre confines the propagating waves inside it by utilizing the property of total internal reflection of light from a dielectric interface

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Relative refractive index

- Fractional refractive index

- If the refractive index of the core material is n_1 and that of cladding material is n_2, a quantity Δn_r is defined as,

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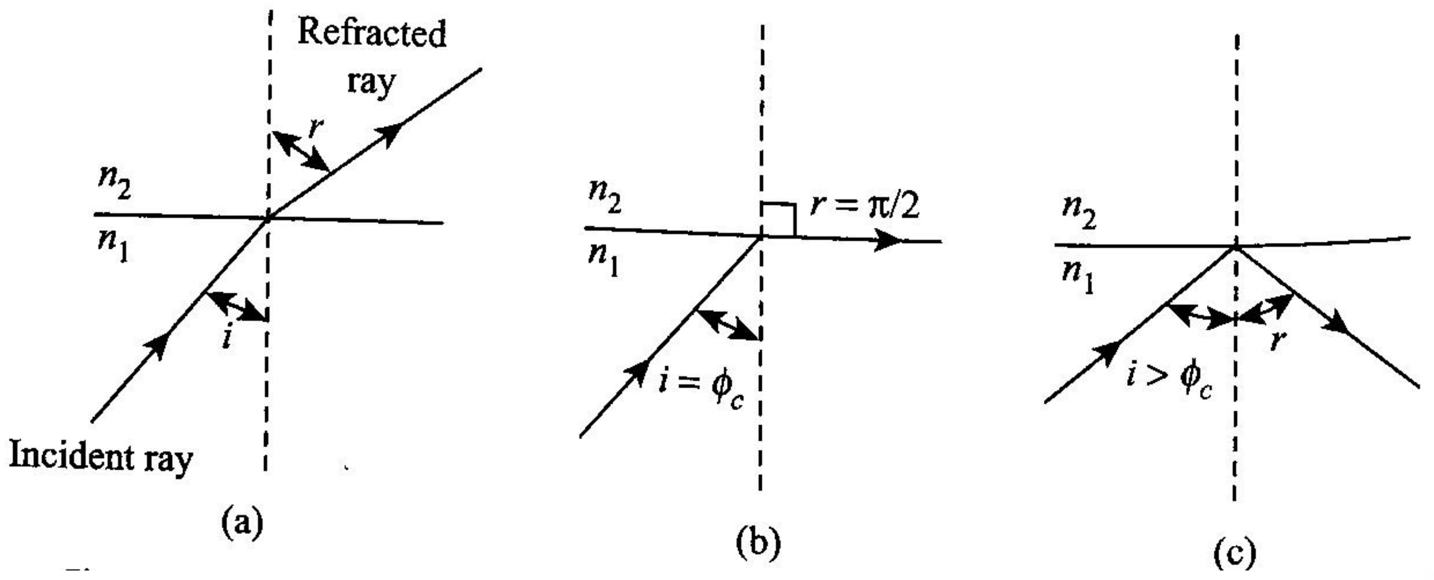
Total internal reflection

- Refraction is governed by Snell's law

$$n_1 \text{ Sin}(i)=n_2 \text{ Sin}(r)$$

- Def: Phenomenon of re-entering of the refracted ray into the medium from which the ray incident on the interface originated is called *total internal reflection*

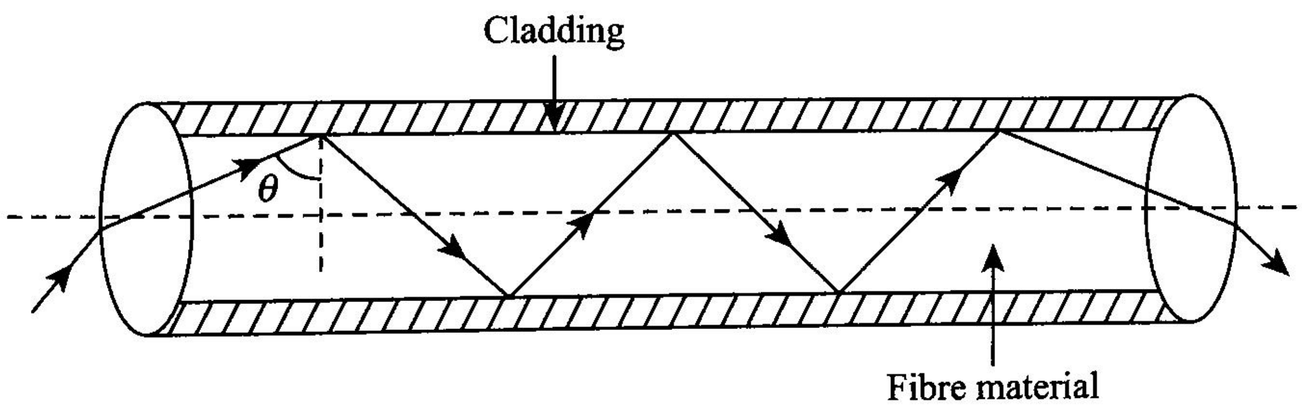


Total internal reflection

- Snell's law for TIR

$$\sin(i=\theta_c)/\sin(r=90)=n_2/n_1$$

$$\sin(\theta_c)= n_2/n_1$$



Acceptance angle

- $\Phi=(\pi/2)-\theta$
- Acceptance angle=Half angle α_m (corresponding to θ_c)

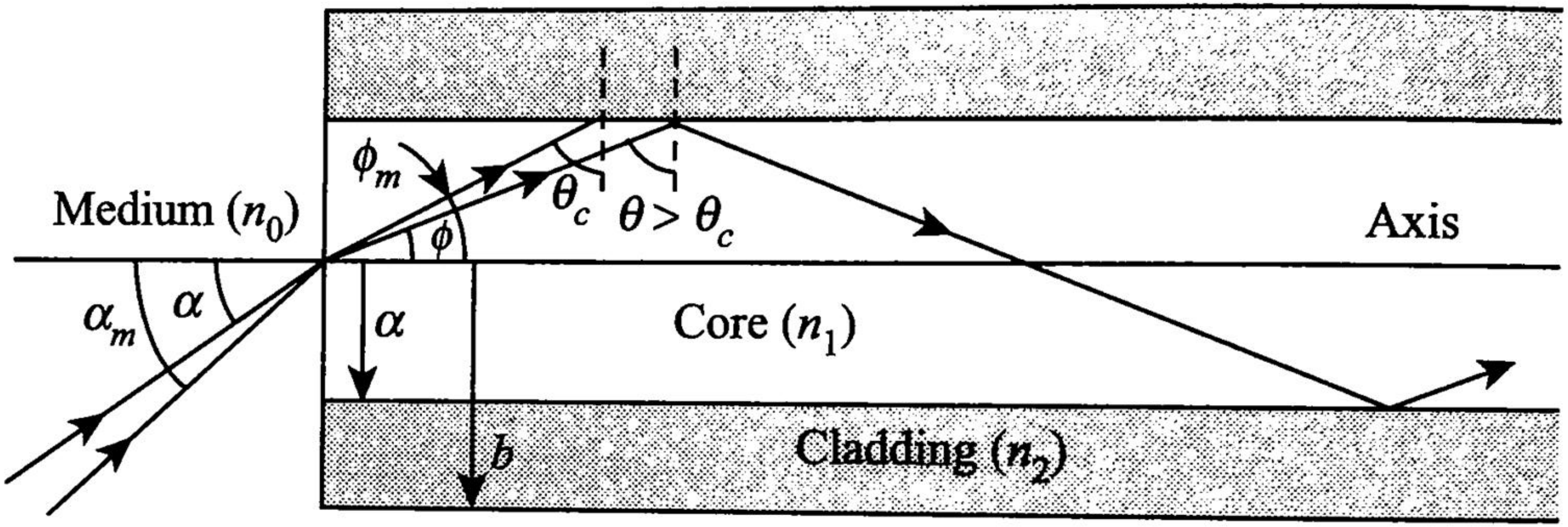
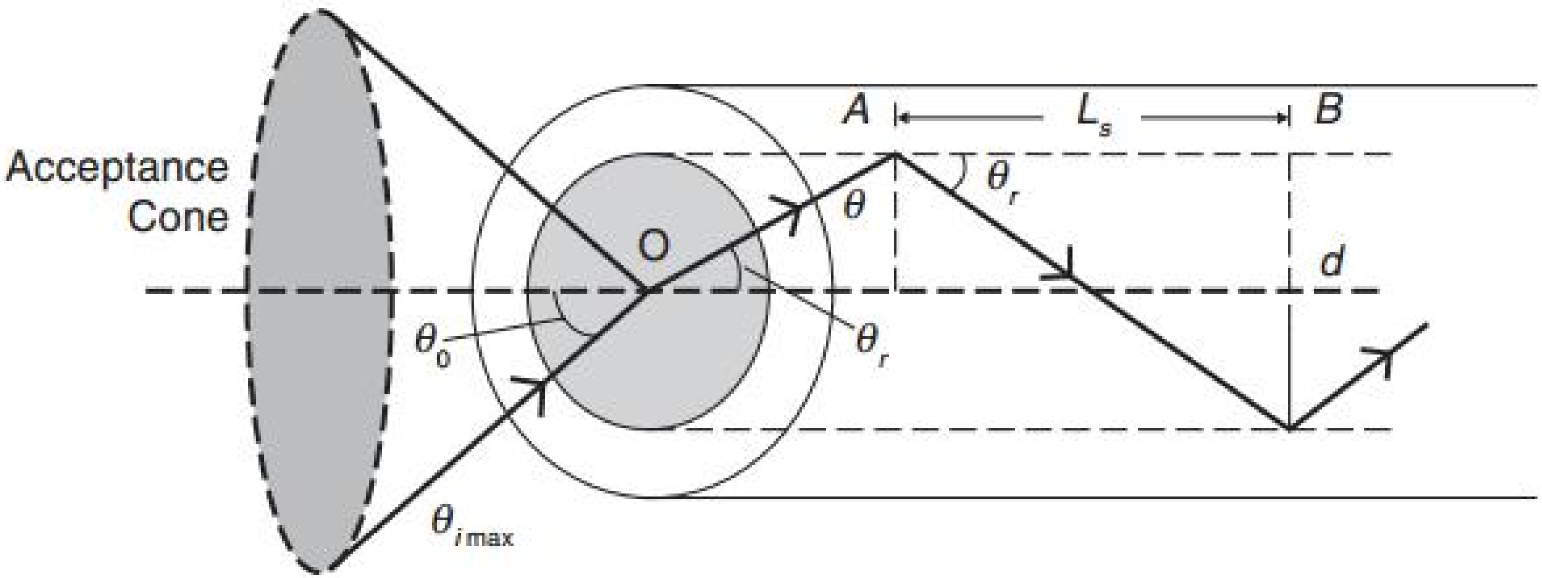
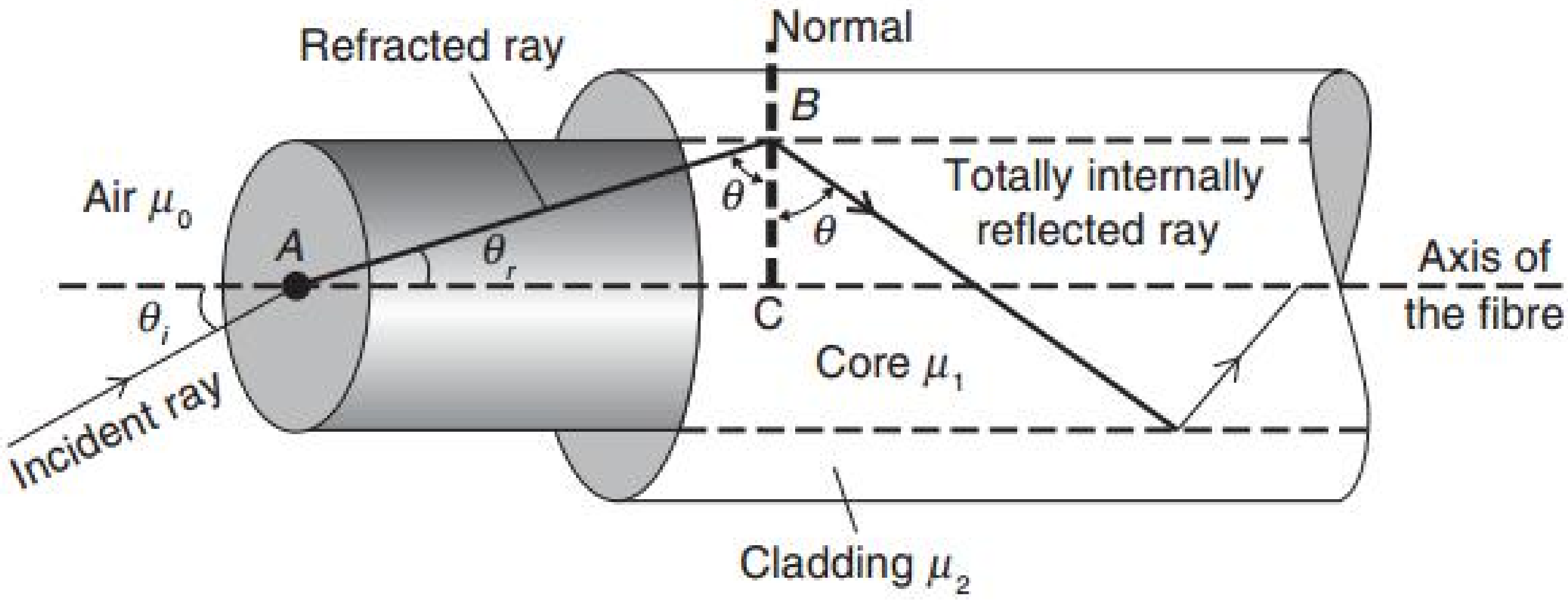


Fig. 5.3 Propagation of light in optical fibre

Acceptance cone

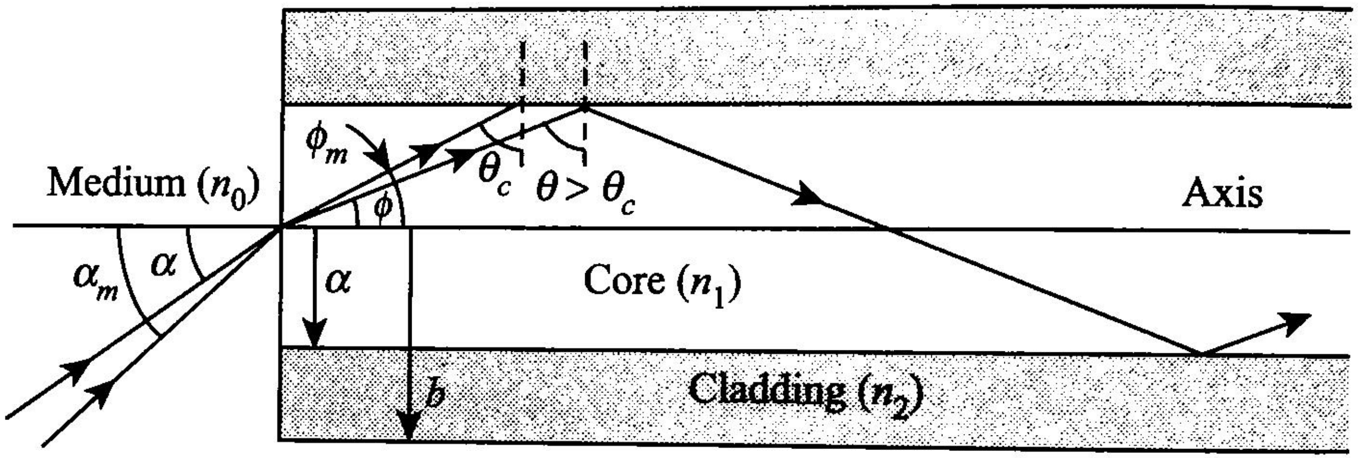


Acceptance angle



Numerical aperture & Acceptance angle

- Application of Snell's law at the core-air interface



$$n_0 \sin \alpha = n_1 \sin \phi$$

$$n_0 \sin \alpha_m = n_1 \sin \phi_m$$

$$\phi_m = \frac{\pi}{2} - \theta_c$$

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The use of Eq. (5.6) in Eq. (5.5) yields the following expression:

$$n_0 \sin \alpha_m = n_1 \cos \theta_c \tag{5.7}$$

We can write that

$$\cos \theta_c = [1 - \sin^2 \theta_c]^{1/2} \tag{5.8}$$

The use of Eq. (5.3) in Eq. (5.8) leads to the following expression:

$$\cos \theta_c = \left[1 - \frac{n_2^2}{n_1^2}\right]^{1/2}$$

which gives the following relation:

$$\cos \theta_c = \frac{\left(n_1^2 - n_2^2\right)^{1/2}}{n_1} \tag{5.9}$$

Substitution of Eq. (5.9) into Eq. (5.7) results in the following expression:

$$n_0 \sin \alpha_m = n_1 \frac{\left(n_1^2 - n_2^2\right)^{1/2}}{n_1}$$

which implies that

$$n_0 \sin \alpha_m = (n_1^2 - n_2^2)^{1/2} \tag{5.10}$$

The term $n_0 \sin \alpha_m$ is called the *numerical aperture* (NA) for an optical fibre. The numerical aperture decides the light-gathering capacity of a fibre. Thus, we can write the following expression:

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Numerical aperture

$$NA = (n_1^2 - n_2^2)^{1/2} \tag{5.11}$$

Let us define a quantity called relative refractive index difference Δ by the following expression:

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \tag{5.12}$$

The use of Eq. (5.12) in Eq. (5.11) leads to the following relation:

$$NA = n_1\sqrt{2\Delta} \tag{5.13}$$

Numerical aperture is a measure of the quantity of light that can be collected by an optical fibre. The light-gathering capability of an optical fibre increases with an increase in its numerical aperture. From Eqs (5.10) and (5.11), it is clear that NA = sin α_m for $n_0 = 1$. Since the maximum value of sin α_m can be 1, NA cannot exceed 1. For $\alpha_m = 90$, NA = 0; that is, the fibre completely reflects the incident light. Numerical apertures of practical optical fibres generally fall in the range of 0.2–1.

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Numerical

(1) for an optical fibre with a glass core (n_1=1.5) and a fused quartz cladding (n_2=1.46), determine the (1) critical angle, (2) acceptance angle and (3) NA. The source to fibre medium is air

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