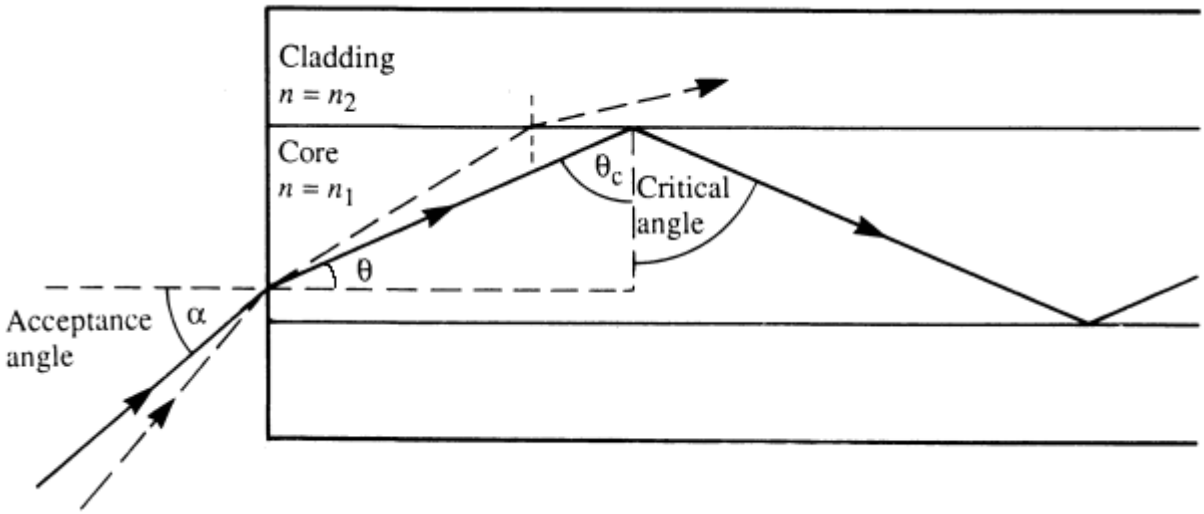
Answer on Question #39487, Physics, Optics

The core and cladding of an optical fiber has refractive indices 1.52 and 1.47 respectively. Find the numerical aperture?

Solution:

Optical fibers are fine transparent glass or plastic fibers which can propagate light. They work under the principle of total internal reflection from diametrically opposite walls. An optic fiber consists of a core that is surrounded by a cladding which is normally made of silica glass or plastic. The core transmits an optical signal while the cladding guides the light within the core.



In order to understand the propagation of light through an optical fiber, consider the figure. Consider a light ray entering the core, travelling through the core until it reaches the core cladding boundary. As long as the light ray intersects the core-cladding boundary at a small angles, the ray will be reflected back in to the core to travel on where the process of reflection is repeated i.e., total internal reflection takes place. Total internal reflection occurs only when the angle of incidence is greater than the critical angle.

Consider an optical fiber having a core of refractive index n_1 = 1.52 and cladding of refractive index n_2 = 1.47.

By Snell's law at the point of entrance of light in to the optical fiber we get,

$$n_0 \sin \alpha = n_1 \sin \theta$$

where n_0 is refractive index of medium outside the fiber. For air n_0 =1.

When light travels from core to cladding it moves from denser to rarer medium and so it may be totally reflected back to the core medium if incident angle exceeds the critical angle θ_c. The critical angle is that angle of incidence in denser medium (n_1) for which angle of refraction become 90°. Using Snell's laws at core cladding interface,

$$n_1 \sin \theta_c = n_2 \sin 90°$$

or

$$\sin \theta_c = \frac{n_2}{n_1}$$

Therefore, there is maximum value of angle of incidence beyond which, it does not propagate rather it is refracted into cladding medium. This maximum value of α is called maximum angle of acceptance and $n_0 \sin\alpha$ is termed as the numerical aperture (NA).

$$NA = n_0 \sin\alpha = n_1 \sin\theta = n_1 \sin(90° - \theta_c)$$

or

$$NA = n_1 \cos(90° - \theta_c) = n_1\sqrt{1 - \sin^2\theta_c} = n_1\sqrt{1 - \left(\frac{n_2}{n_1}\right)^2}$$

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

$$NA = \sqrt{1.52^2 - 1.47^2} = 0.39$$

Answer. NA = 0.39.