Assist.Prof. Dr. Muhanad rasheed

Al-Rasheed University College

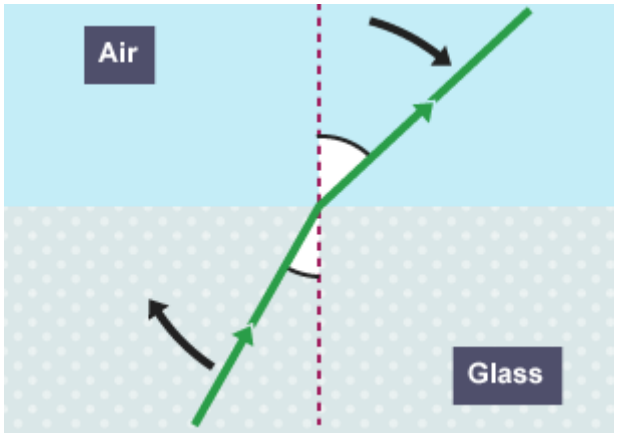
DEP. OF MEDICAL INSTUMENTATION TECHNIQUES ENGINEERING

Lecture 4:

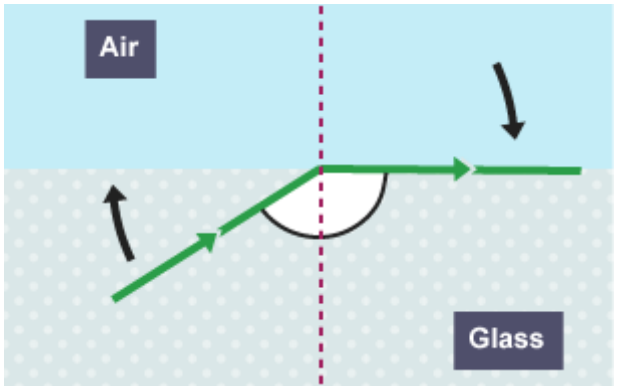
Light Propagation in Glass Fiber

1. Propagation of light refers to the manner in which an electromagnetic wave transfer its energy from one point to another. Three main processes generally occur when light passes between boundaries from one medium to another: Transmission, Reflection, Refraction.
2. Refraction occurs when waves travel from one material to another. For light, this can change both the speed and direction.
3. . An **optical fiber** is a thin strand of high-quality glass. Light can be transmitted through it over very large distances.
4. **Total internal reflection and the critical angle**

(a) When a ray of light leaves a denser medium, it moves away from the normal.

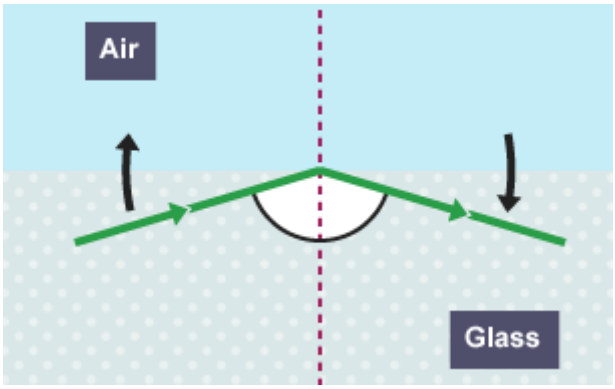


(a) As the angle of incidence inside the material increases, the angle of refraction increases, to a point at which it leaves the material at 90˚.



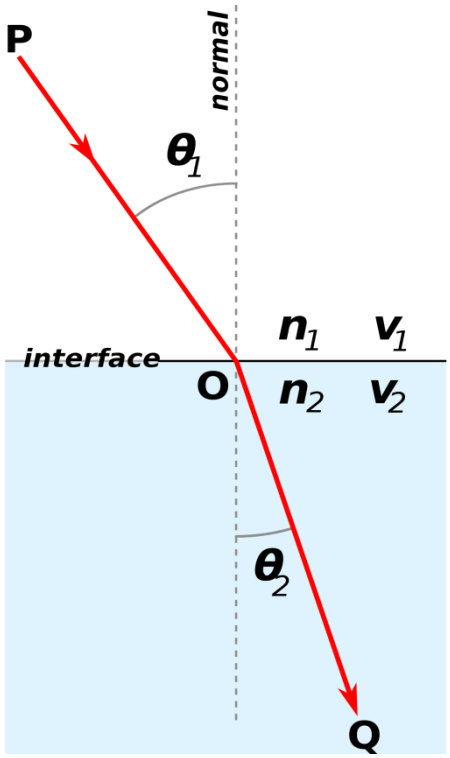
(b) The minimum angle at which total internal reflection occurs is known as the **critical angle** (for Perspex this is about 43˚). At any angle greater than the critical angle, total internal reflection (TIR) occurs and the light ray obeys the normal rules for reflection (i.e., angle of incidence = angle of reflection).

If the angle of incidence is increased any more, then the ray does not exit glass into the air, but is reflected inside the glass. As none of the light refracts into the air, the ray has been totally internally reflected inside the material.



Snell's Law

1. light experiences the refraction or bending when it travels from one medium to another medium.
2. Snell's law gives the degree of refraction and relation between the angle of incidence, the angle of refraction and refractive indices of a given pair of media.
3. Snell's law is defined as :



$$n_1 sin\theta_1 = n_2 sin\theta_2$$

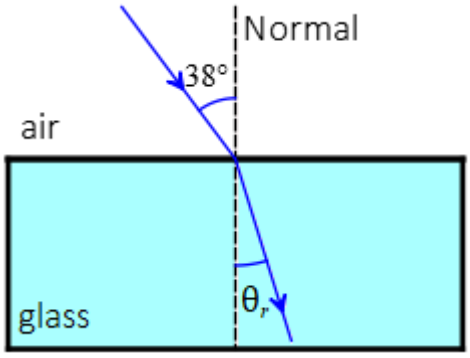
θ_1 = angle of incidence

θ_2 = angle of refraction

4. Snell's law has a wide range of applications especially in the branch of glass fibers. It is used in optical apparatus such as eyeglasses, contact lenses, cameras. There is an instrument called a Refractrometer that uses Snell's law to calculate the refractive index of liquids.

5. **Examples for Snell's law :**

(1) A beam of laser traveling in air incident on a surface of a thin glass at an angle of 38^0 with the normal. The index of refraction of the glass is 1.56. What is the angle of refraction?



By applying Snell's law :

$$n_1 sin\theta_1 = n_2 sin\theta_2$$

$1 \times \sin 38 = 1.56 \times \sin \theta_2$

$\sin \theta_2 = \frac{\sin 38}{1.56} = 0.3947$

$\theta_2 = \sin^{-1}(0.3947) = 23.25^0$

(2) If the angle of incidence is 25° and angle of refraction is 32°, find the refractive index of the media.

$\Theta_1 = 25^0$, $\theta_2 = 32^0$

$1 \times 25 = n_2 \times 32$ ..... $n_2 = \frac{25}{32} = 0.78 \approx 0.8$

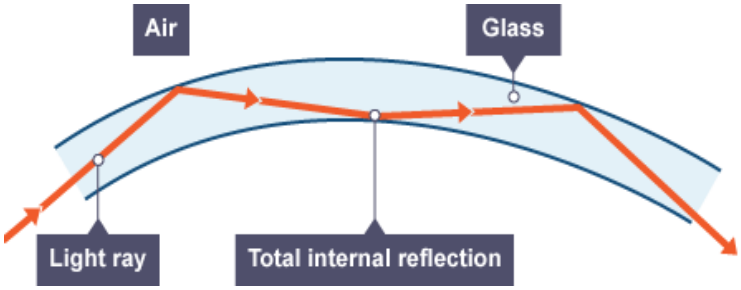
(3) Light travels from air into an optical fiber with an index of refraction of 1.44.

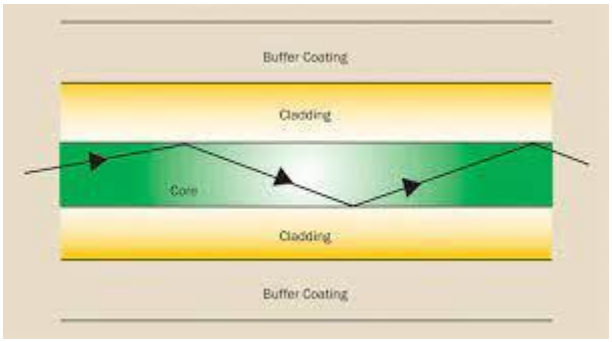
(a) In which direction does the light bend?
(b) If the angle of incidence on the end of the fiber is 22°, what is the angle of refraction inside the fiber?

$n_1 = 1.00, n_2 = 1.44$, $\theta_1 = 22^o$

$1 \times \sin 22^o = 1.44 \times \sin \theta_2$.
$\sin \theta_2 = (1/1.44) \sin 22^o = 0.260$
$\theta_2 = \sin^{-1} (0.260) =$ **15°**

1. Light travels from one end to the other of an optical fiber **by total internal reflection**, even when the fiber is bent. Very little light is absorbed in the glass fiber.



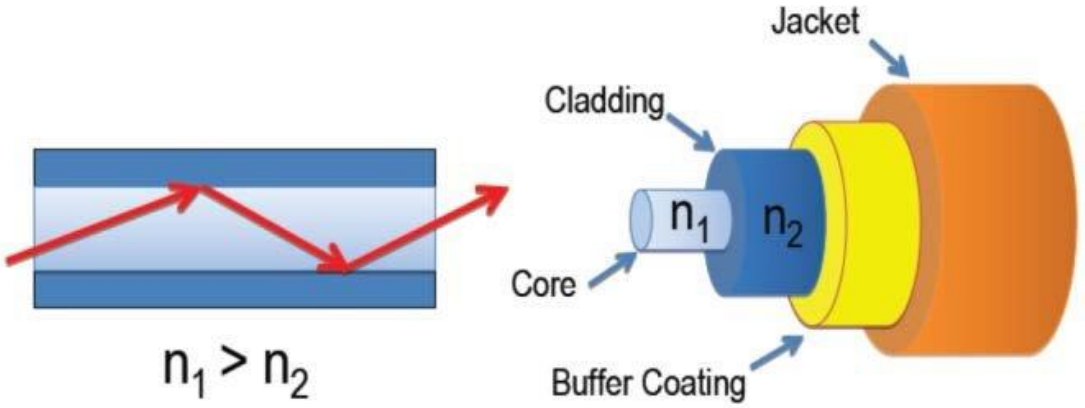


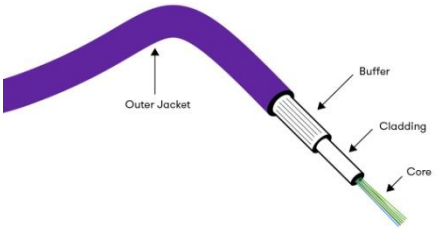
2. Optical fibers are used in telecommunications and medical affairs because they can carry lasers and enormous amounts of information in laser light pulses trapped inside them. This information is carried at very high speed

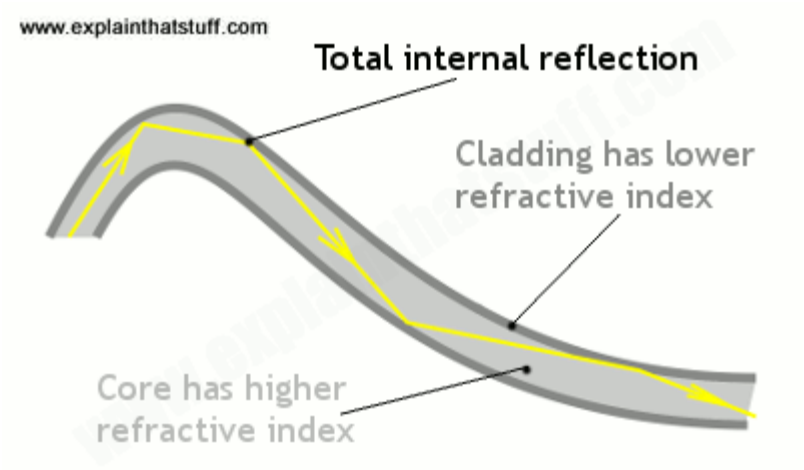
($\approx 2\times10^{8}\ ms^{-1}$) along an optical fiber cable. Fiber optic communication can transmit much more data at once.

Optical fibers are an extremely thin and long strand of very fine quality glass or quartz coated within a thin layer of material of

1. refractive index less than the refractive index of the strand. It works on the principle of TIR (total internal reflection).



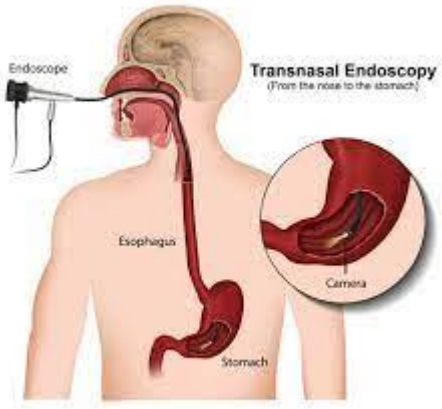




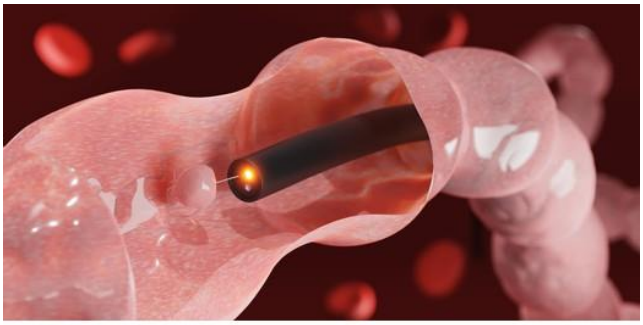
1. When light falls one end of the optical fiber; it gets refracted into the fiber. The refracted ray of light falls on the interface separating the fiber and coating with an angle greater than the critical angle. Thus the TIR can take place. The light travels the entire length of the fiber and arrives at other ends of the fiber with little loss in its intensity even if the fiber is rounded and curved.
2. There are two limitations that an optical fiber has. The first one is the actual loss of light as it travels through the fiber and the other one is a maximum limit of the bandwidth of the signals that can be carried.

3. Applications of optical fibers in Medicine

i. The most significant and prevalent applications of fiber optics in medicine are in the imaging and illumination components of endoscopes.



ii. Low-loss optical fibers are employed to transmit laser energy for surgery and photocoagulation. Multicolor laser light is transmitted through a single thin optical fiber to provide adequate illumination for viewing and color photography.



shutterstock.com · 1911546763