Snell's Law

When light travels from one medium to another, its **velocity** and **wavelength** change, but its **frequency** remains constant. Snell's Law can also be written as:

$$\frac{\sin\theta_1}{v_1} = \frac{\sin\theta_2}{v_2}$$

$$v_1 = f\lambda_1$$

$$v_2 = f\lambda_2$$

f = constant, $v_1 \neq v_1$, $\lambda_1 \neq \lambda_2$

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\frac{c}{n_1}}{\frac{c}{n_2}} = \frac{n_2}{n_1}$$

$$\lambda_1 n_1 = \lambda_2 n_2$$

Where, v is the velocity of light in the medium, f is the frequency and λ is the wavelength. The angles θ_1 and θ_2 are measured relative to the normal line to the surface between the two materials.

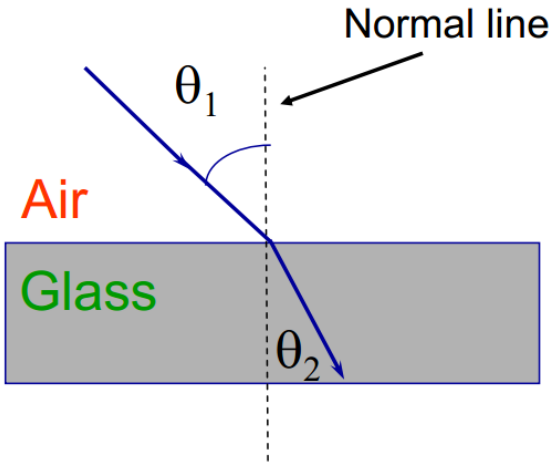


Figure 5 Refraction of light in the medium

Ex4:

A light ray of wavelength (650 nm) travel through Air is incident on smooth, flat quartz with refractive index (1.458). Find the velocity of light, wavelength and frequency in quartz?

Solution:

the velocity of light in quartz :

$$v = \frac{c}{n} = \frac{3 \times 10^8}{1.458} = 2.048 \times 10^8\ m/s$$

The wavelength:

$$\lambda_1 n_1 = \lambda_2 n_2$$

$$650 \times 1 = \lambda_2 \times 1.458$$

λ_2 =445.8 nm

The frequency:

$$f = \frac{v_2}{\lambda_2} = \frac{2.048 \times 10^8\ m/s}{445.8 \times 10^{-9}\ m} = 4.6 \times 10^{14}\ Hz$$

Total Internal Reflection

When light travels from a medium with $n_1 > n_2$ (from high density to the low density medium), and $\theta_2 = 90°$ there is an angle, called the **critical angle** (θc), at which all the light is reflected and none is transmitted. This process is known as total internal reflection.

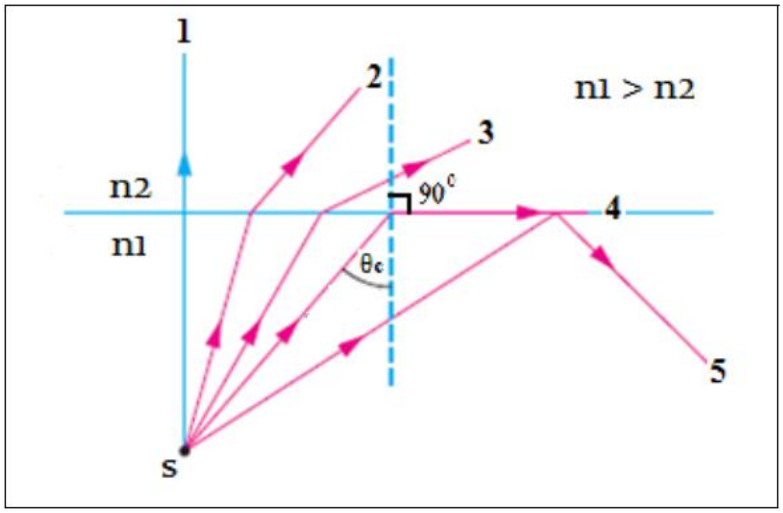


Figure 6 critical angle

From fig (), we can see light ray (1) transmit without refraction, because it incident perpendicularly on the surface. Whereas, light ray (2) refract away from normal line. Also, light ray (3) refract more than ray (2), [*refraction angle increases when incident angle increases*]. Light ray (4) make refraction angle (90°) ,the incident angle called (**critical angle**) and the refracted light will be parallel to the interval surface.

$$\theta_1 = \theta_c$$

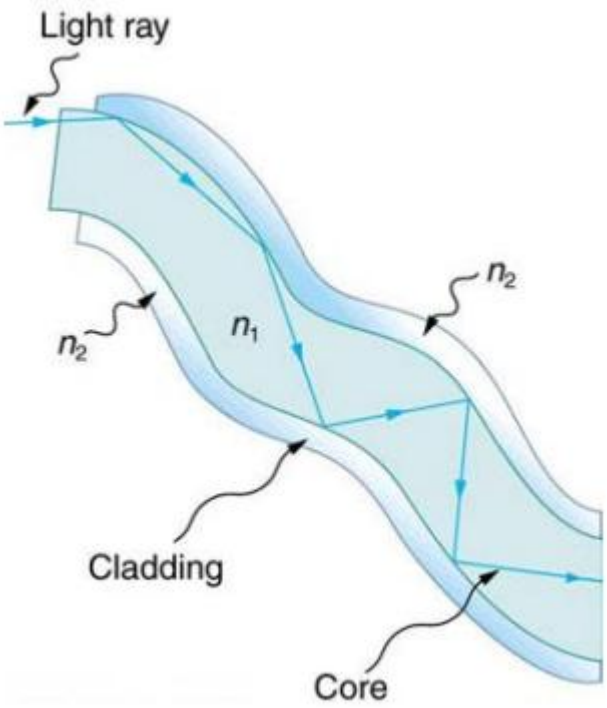
$$\theta_2 = 90°$$

$$n_1 \sin\theta c = n_2 \sin 90$$

$$\theta_c = \sin^{-1}\frac{n_2}{n_1}$$

Application of total internal reflection

Fiber optics is one application of total internal reflection that is in wide use. In communications, it is used to transmit telephone, internet, and cable TV signals. Fiber optics made of plastic or glass. Because the fibers are thin, light entering inside surface at an angle **greater** than the critical angle and, thus, be totally reflected. Fibers are surrounded by a cladding material that has a lower index of refraction than the core.



Figure

Figure 7 Optical fiber

3. Dispersion (The Rainbow and Prisms)

(*It is defined as the spreading of white light into its full spectrum of wavelengths*). How does sunlight falling on clear drops of rain get broken into the rainbow of colors we see? The same process causes white light to be broken into colors by a clear glass prism or a diamond. We see about **six colors** in a rainbow—red, orange, yellow, green, blue, and violet. **(The colors of the rainbow and those produced by a prism are identical).**Refraction is responsible for dispersion , index of refraction *n* increases as wavelength decreases and is greatest for violet light. Thus violet light is bent more than red light. Red deviates the least. [In optical systems, since a laser produces a nearly pure wavelength, its light experiences little dispersion, an advantage over white light for transmission of information].

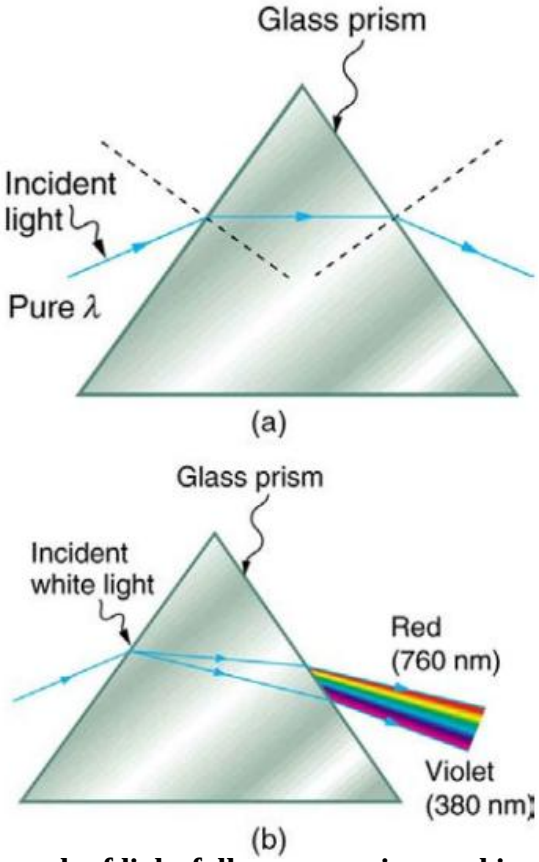


Figure 8 A pure wavelength of light falls onto a prism and is refracted at both surfaces. (b) White light is dispersed by the prism

Rainbows are produced by a combination of refraction and reflection. Light enters a drop of water and is reflected from the back of the drop. The light is refracted both as it enters and as it leaves the drop.

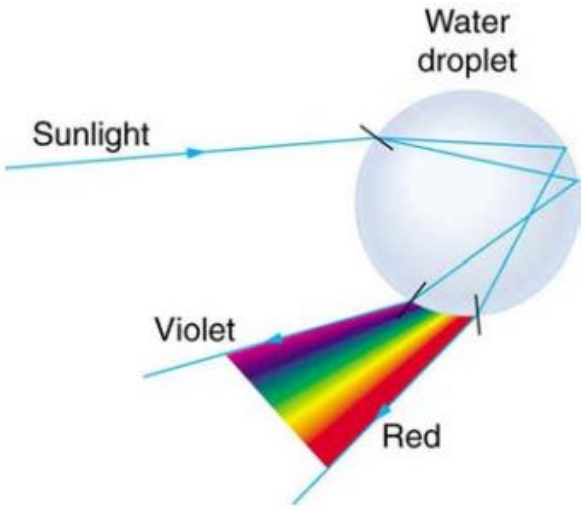


Figure 9 Rainbow