16.2.3: Total Internal Reflection

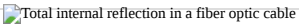

Figure 14.3.1

Total internal reflection allows the light to travel down the optical fiber and not pass through the sides of the tube. The light continuously reflects from the inside of the tube and eventually comes out the end. Optical fibers make interesting lamps but they are also used to transport telephone and television signals.

Total Internal Reflection

We already know that when light passes from one medium into a second medium where the index of refraction is smaller, the light refracts away from the normal.

In the image below, the light rays are passing into an optically less dense medium; therefore, the rays bend away from the normal. As the angle of incidence increases, the light ray bends even further away from the normal. Eventually, the angle of incidence will become large enough that the angle of refraction equals $90\circ$, meaning the light ray will not enter the new medium at all.

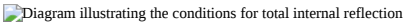

Figure 14.3.1

Consider a ray of light passing from water into air. The index of refraction for air is 1.00 and for water is 1.36. Using Snell's Law, $n_i\sin\theta i = n_r\sin\theta r$, and allowing the angle of refraction to be 90°, we can solve for the angle of incidence which would cause the light ray to stay in the old medium.

$n_i\sin\theta_i = n_r\sin\theta_r$

$(1.36)(\sin\theta_i) = (1.00)(\sin 90^\circ)$

$\sin\theta_i = 0.735$ *and* $\theta_i = 47^\circ$

This result tells us that when light is passing from water into air, if the angle of incidence exceeds 47°, the light ray will not enter the new medium. The light ray will be completely reflected back into the original medium. This is called **total internal reflection**. The minimum angle of incidence for total internal reflection to occur is called the **critical angle**.

Total internal reflection is the principle behind **fiber optics**. A bundle of fibers made out of glass or plastic only a few micrometers in diameter is called a light pipe since light can be transmitted along it with almost no loss. Light passing down the fibers makes glancing collisions with the walls so that total internal reflection occurs.

Use the Diamond Cut simulation below to adjust the shape of a diamond with the three sliders related to depth, crown, and table size. Try to find a combination of sliders for which the light is trapped inside - achieving total internal reflection - and a very sparkly diamond!

Summary

- When light passes from one medium into a second medium with a smaller index of refraction, the light refracts away from the normal.
- If the angle of incidence becomes large enough that the angle of refraction equals $90\circ$, the light ray will not enter the new medium with the smaller angle of refraction.
- Total internal reflection means the light ray will not enter the new medium but will be completely reflected back into the original medium.

Review

1. Find the critical angle for light passing from diamond into air, given $n_{diamond}=2.42$.
2. When two swimmers are under water in a swimming pool, it is possible for the interface between the water and the air to act as a mirror, allowing the swimmers to see images of each other if they look up at the underside of the surface. Explain this phenomenon.
3. Robert shines a laser beam through a slab of plastic and onto the interface between the slab of plastic and the air on the other side. The index of refraction for the plastic is 1.62. If the angle of incidence in the plastic is 54 , will the laser beam pass out of the plastic into the air?

Explore More

Use this resource to answer the questions that follow.

1. What phenomenon occurs when the light does not enter the new medium and remains in the old medium?
2. When does this phenomenon occur?

Additional Resources

Study Guide: Geometric Optics Study Guide

Videos: Geometric Optics 6: Total Internal Reflection - Overview

Real World Application: Light Pipes

PLIX: Play, Learn, Interact, eXplore: Total Internal Reflection

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