Key Concepts

Chapter 10

Refraction

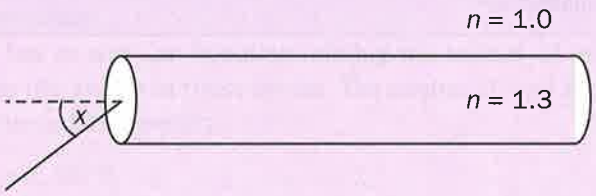
Reflection

Total internal reflection

Snell's law

Total Internal Reflection

Light is directed from air ($n = 1$) into a glass tube ($n = 1.3$). A section is shown below. What is the maximum angle x that ensures that no light escapes the horizontal sides of the tube?



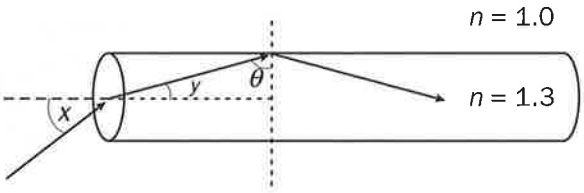
Takeaways

Drawing a diagram is key to solving this problem. The angles must be measured relative to the normal.

Note that the formula for a critical angle can be derived from Snell's law by setting $\theta_2 = 90°$.

1) Draw a diagram of the ray traveling through the tube.

Draw a diagram of the ray entering the tube and reflecting off of the horizontal side. Draw the normal to each surface where the ray strikes, because the formulas for refraction are always in terms of the angles measured from the normal. Label the angles θ and y.



Remember: *Light bends in toward the normal when entering a region of higher index of refraction.*

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2) Set θ equal to the critical angle.

If no light escapes from the horizontal side of the tube, then θ must be greater than or equal to the critical angle for the tube. This is referred to as total internal reflection. The critical angle is given by $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$, where n_2 is the index of refraction outside of the tube and n_1 is the index of refraction inside the tube.

$$\theta = \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1}{1.3}\right) = 50.3°$$

Remember: *Total internal reflection can only occur when going from a higher index to a lower index of refraction.*

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3) Find *y* from θ.

θ and *y* are two angles of a right triangle. The sum of the angles of a triangle is 180°. Solve for angle *y*.

$\theta + y + 90 = 180$
$y = 90 - \theta = 39.7°$

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4) Use Snell's law to find *x*.

Snell's law relates the indices of refraction for the two materials to the angles (measured relative to the normal) on both sides of the interface. This law is used to determine what happens when a light ray refracts. Plug in the value for *y* from step 3 and solve for *x*.

generic: $n_1 \sin \theta_1 = n_2 \sin \theta_2$
(1) $\sin x = (1.3) \sin 39.7°$
$x = \sin^{-1} [(1.3) \sin 39.7°] = 56.1°$

Similar Questions

1) The critical angle for a certain interface is 35°. If the index of refraction of one material is 1.6, what is the index of refraction of the other material?
2) Light from air strikes a translucent plastic material. If the light strikes at an angle of 30° to the material and bends 15°, what is the index of refraction of the plastic?
3) Light enters a glass slab ($n = 1.33$) from a vacuum. After traveling through the glass, it travels through a fluid ($n = 1.6$), through another section of glass, and then back into a vacuum. The two glass and fluid sections are parallel to each other. If the light enters the first glass slab at an angle of 35° to the normal, at what angle does it leave the final glass slab?