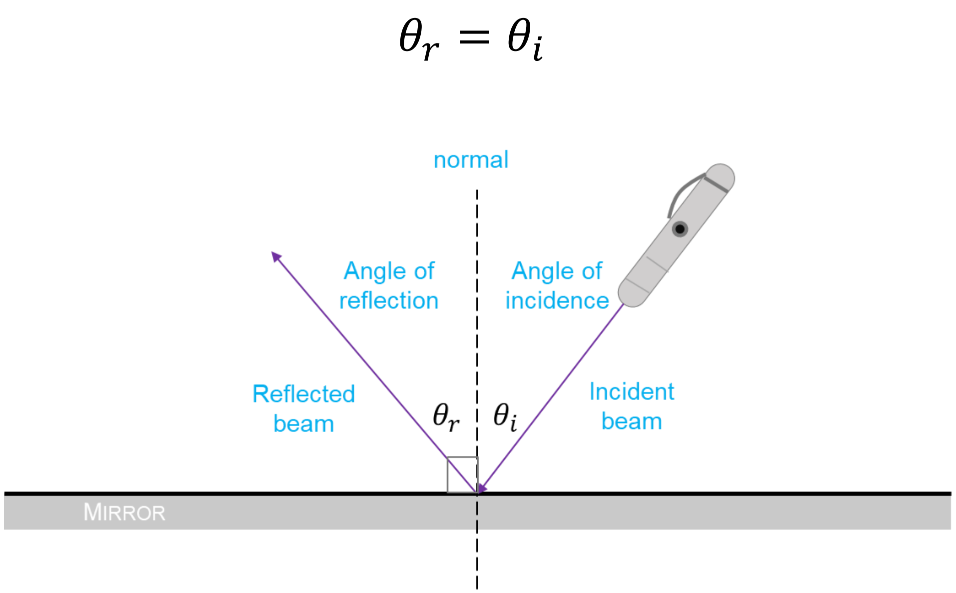
CHAPTER 22: REFLECTION AND REFRACTION

REFLECTION



Law of reflection

When a narrow beam of light, represented by one ray, shines on a smooth surface such as mirror, the angle between the incident ray and the normal line perpendicular to the surface equals to the angle between the reflected ray and the normal line (**the angle of reflection equals the angle of incidence**).
The incident beam, reflected beam, and the normal line are always in the same plane.

REFRACTION

Snell's Law relates the refraction angle θ_2 to the incident angle θ_1 and the indexes of refraction of the incident medium n_1 and the refracted medium n_2:

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

SNELL'S LAW

From the observations similar to those we have just done, Snell formulated the mathematical model for refraction phenomena:

$$n_{1\ to\ 2} = \frac{\sin\theta_1}{\sin\theta_2}$$

$n_{1\ to\ 2}$ is the number that depends on the two materials the light is traveling through.
If we split $n_{1\ to\ 2}$ into a ratio of two numbers that depends on the material through which the incident ray travels (n_1) and the other that depends on the material through which the refracted ray travels (n_2), we get

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

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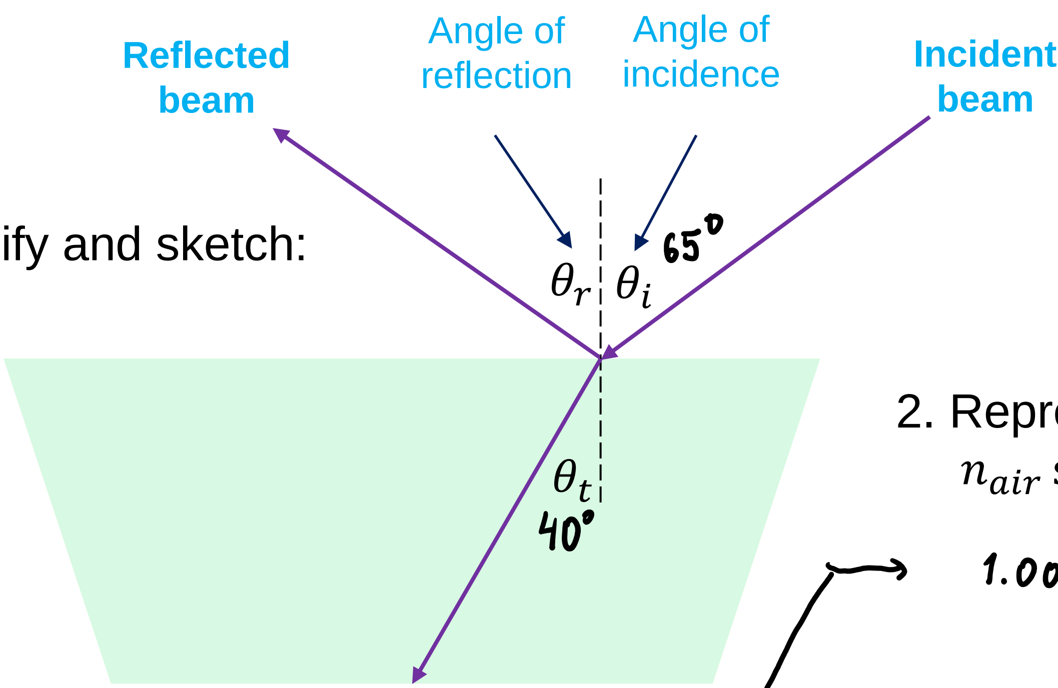
EXAMPLE 22D

Light, originally traveling through air ($n_{air} = 1.001$) reaches an unknown liquid at the angle of 65^o.
What is the refractive index of the liquid if the angle of refraction is 40^o.

1. Simplify and sketch:



2. Represent mathematically:

$$n_{air} \sin \theta_i = n_{liquid} \sin \theta_t$$

$$1.001 \sin 65 = n_l \sin 40$$

$$n_l = \frac{1.001 \sin 65}{\sin 40}$$

$$n_l = 1.41$$

3. Solve! [Learning Catalytics!]

3. Evaluate ✓

EXAMPLE 22E

Activity:
https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html

Exercise 3:

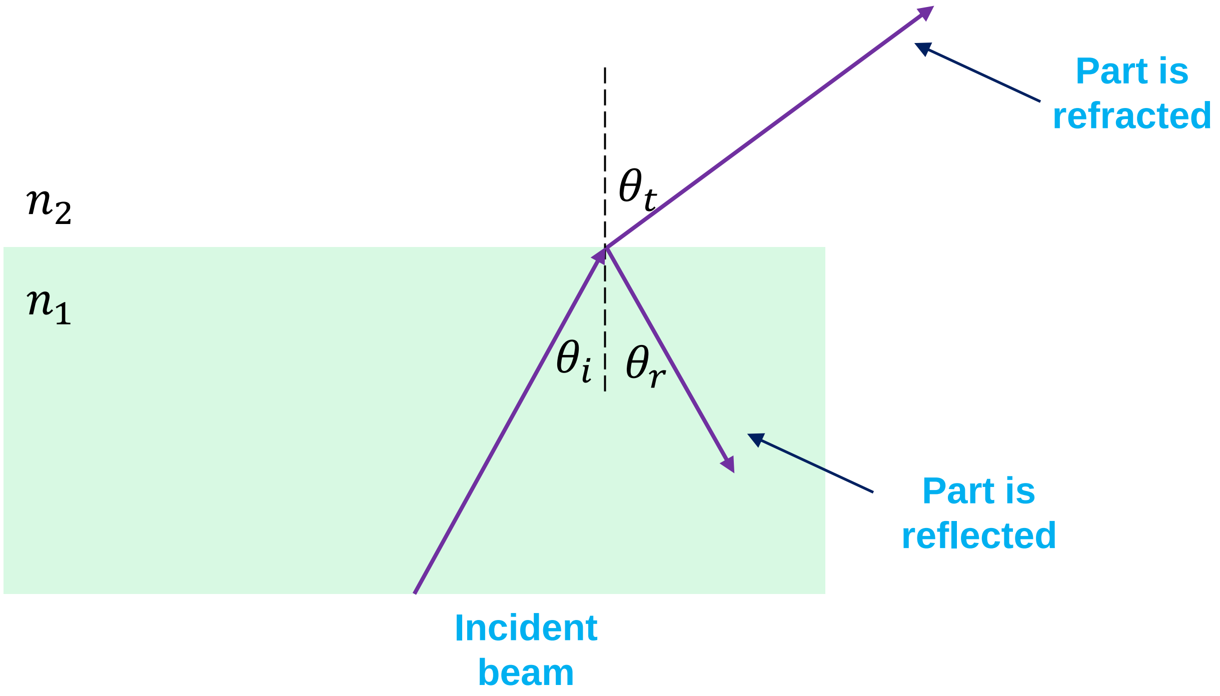
1. Set n (**index of refraction** of the first medium) to 1.6 (Glass)
2. Set the angle of incidence to any value larger than 30^o.
3. Play with the refractive index of the secondary material to detect a value at which you stop seeing the **refracted** beam (all light is reflected). Record the last value of the refractive index for which you still can see the refracted beam.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
$$\theta_2 = 90^o \rightarrow therefore \sin\theta_2 = 1$$

$$n_1 \sin\theta_1 = n_2$$
$$mx = y$$

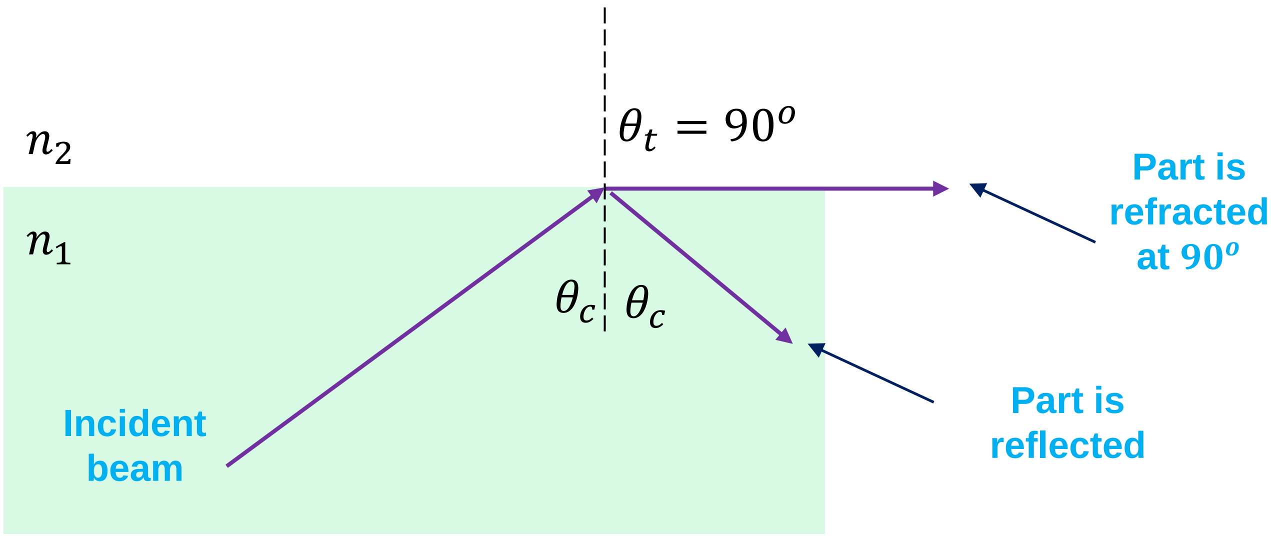
$$y = n_2$$
$$x = \sin\theta_1$$
$$SLOPE\ (m) = n_1$$

22.4 Total Internal Reflection



When $n_2 < n_1$ the refracted ray bends away from the normal and $\theta_t > \theta_i$

22.4 Total Internal Reflection

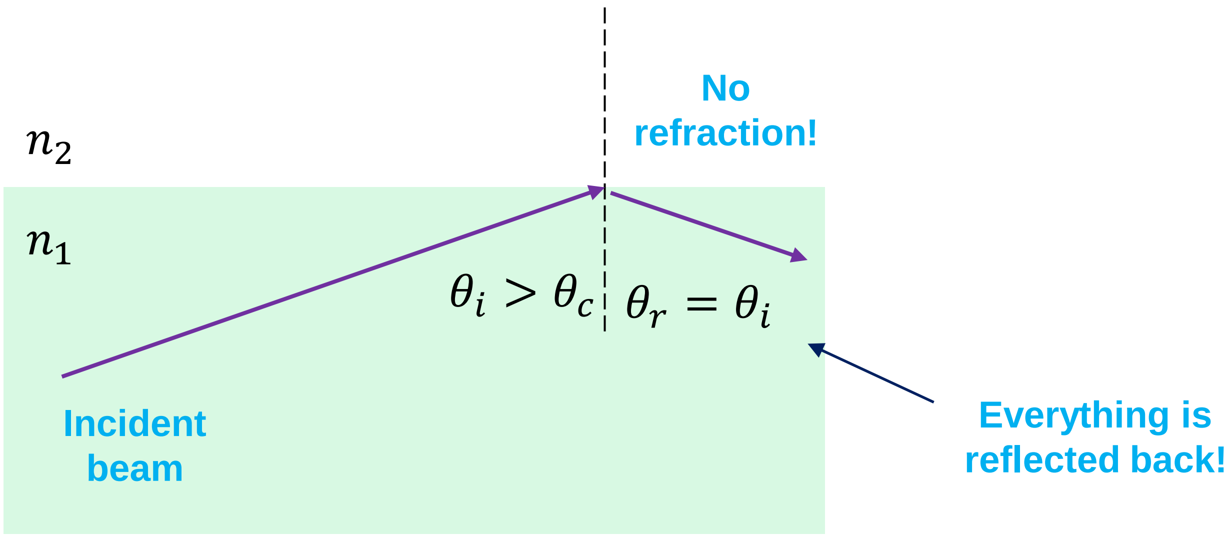


When $\theta_i = \theta_c$ (critical angle, a.k.a Brewster angle), the refracted angle is equal to 90^o.

Snell's law still applies so $n_1 \sin\theta_c = n_2 \sin 90^o = n_2$

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

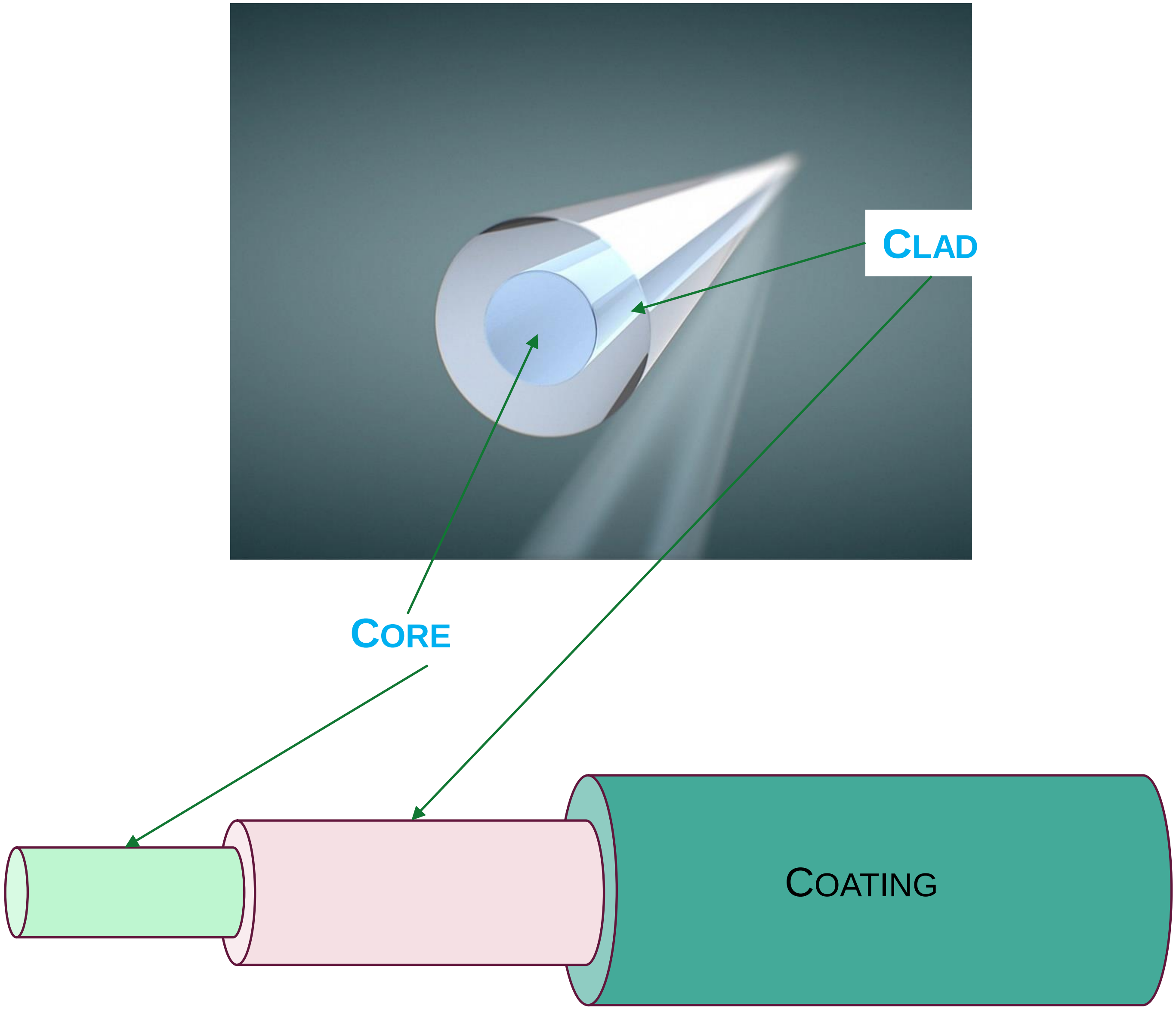
22.4 Total Internal Reflection



Once the critical angle is exceeded, there is no more refraction and all light is reflected back into the medium!

Example 22f

Fiberoptic cable

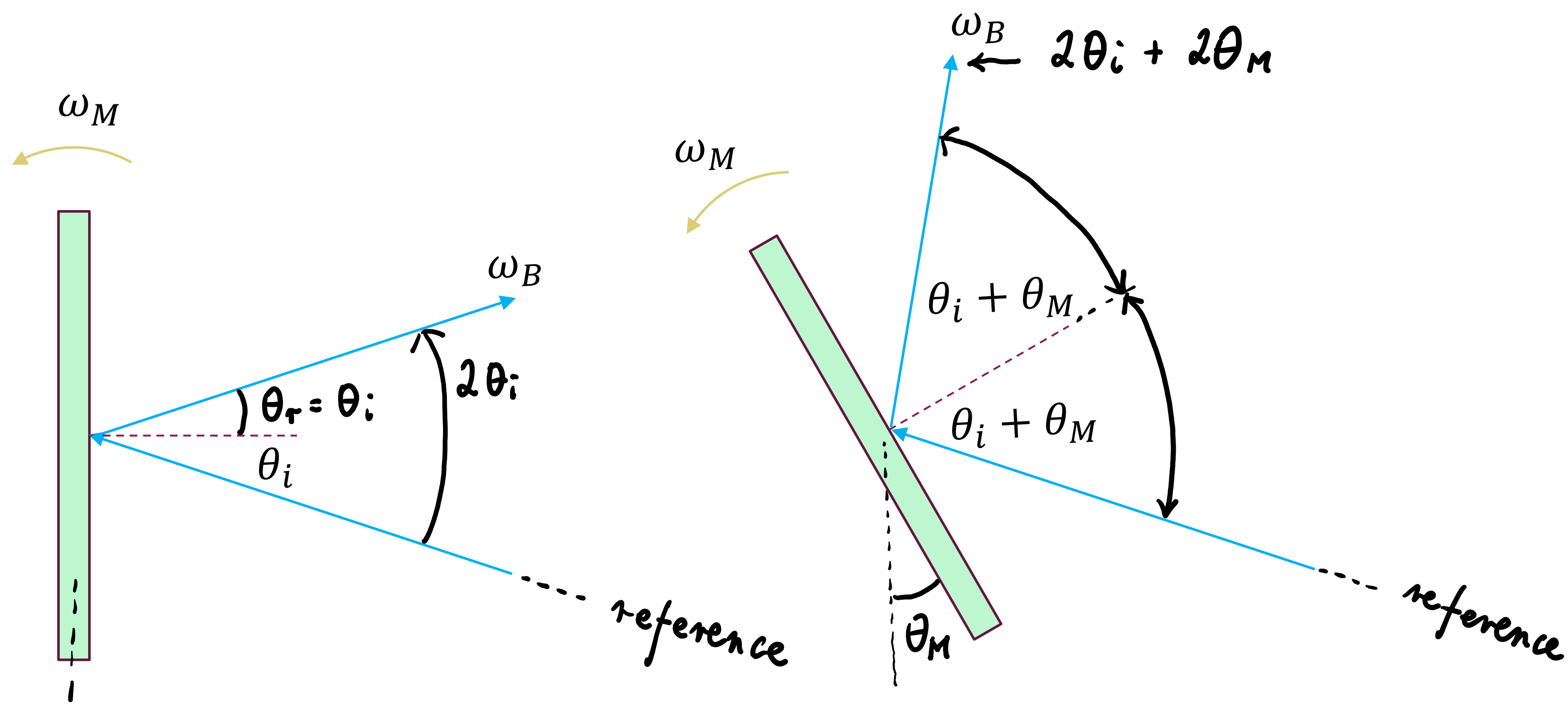


Example 22G

$\Delta\theta_M = \omega_M \Delta t$

Based on "Quantitative Exercise 22.6"

A mirror is rotating with angular speed ω_M.



What is the angular speed ω_B of the reflected light ray?

initial position of reflected beam → $2\theta_i$

with rotation $2\theta_i + 2\theta_M$

$$\omega_B = \frac{(2\theta_M + 2\theta_i) - 2\theta_i}{\Delta t} = \frac{2\theta_M}{\Delta t} = 2\omega_M$$

EXAMPLE 22H

BASED ON "EXAMPLE 22.7"

The question ask about the size of the leaf needed so that any light reflected from the fish and reaching the water surface undergoes total internal reflection and does not leave the water.

Light incident at a smaller angle relative to the normal will hit the leaf.

1. critical angle $n_{air} \cdot \sin 90 = n_w \cdot \sin \theta_c$

$$\frac{n_{air}}{n_w} = \sin \theta_c = \frac{1}{1.35} = 0.74$$

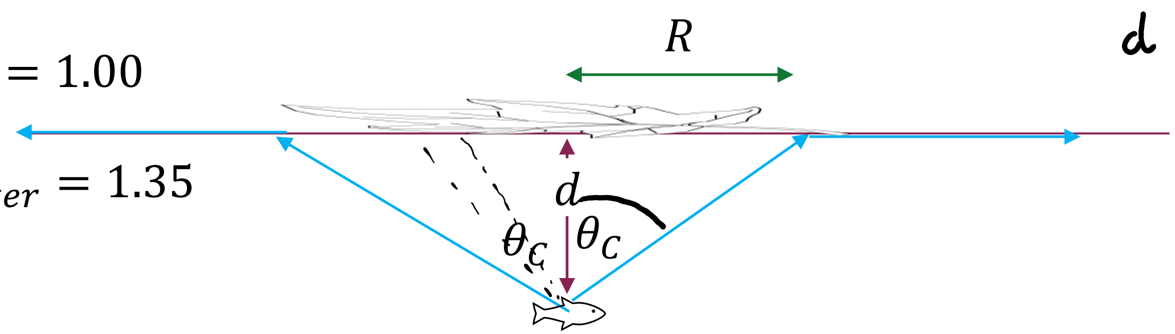
$$\theta_c = 47.8^\circ$$

$\frac{R}{d} = \tan 47.8^\circ$

$n_{air} = 1.00$

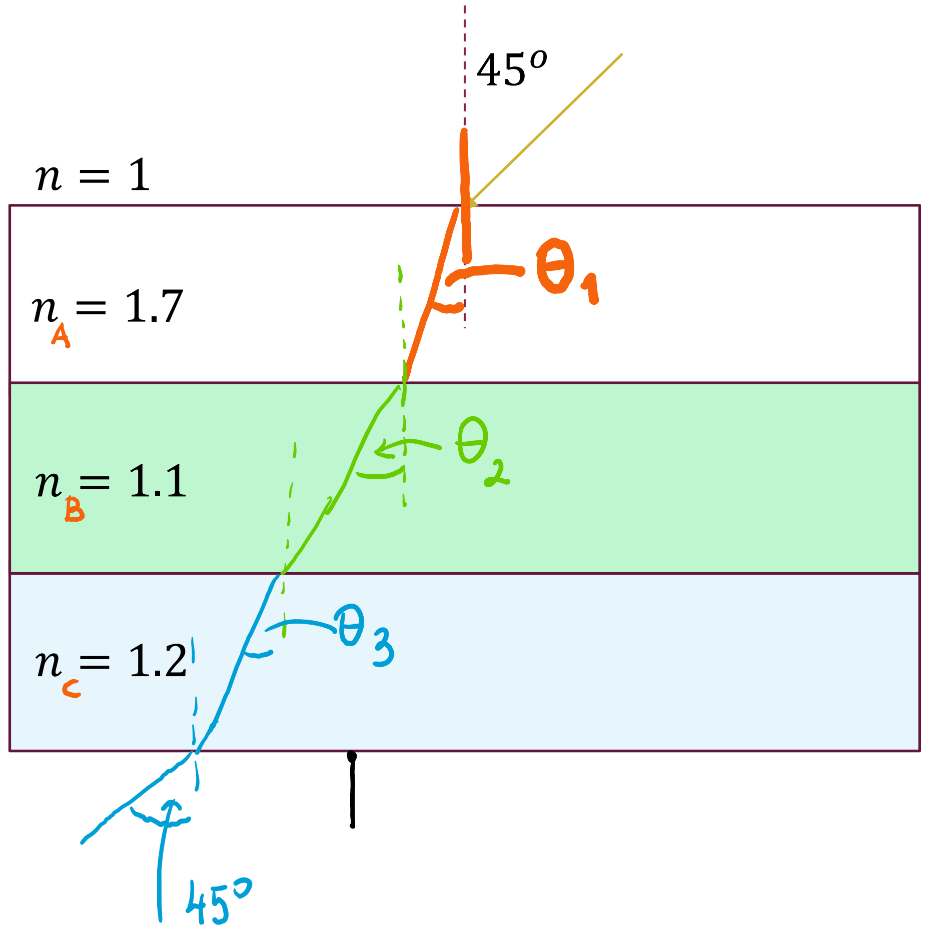
$R = d \cdot \tan 47.8^\circ$

$n_{water} = 1.35$



Example 22i

Mark the path of the rays of light through the layered medium.
Consider both reflected and refractive rays.



$$n \sin 45 = n_A \sin \theta_1$$

$$\sin \theta_1 = \frac{n \sin 45}{n_A} = 0.416$$

$$\theta_1 = 24.5^o$$

$$n_A \sin \theta_1 = n_B \sin \theta_2$$

$$\theta_2 = 40.0^o$$

$$n_B \sin \theta_2 = n_C \sin \theta_3$$

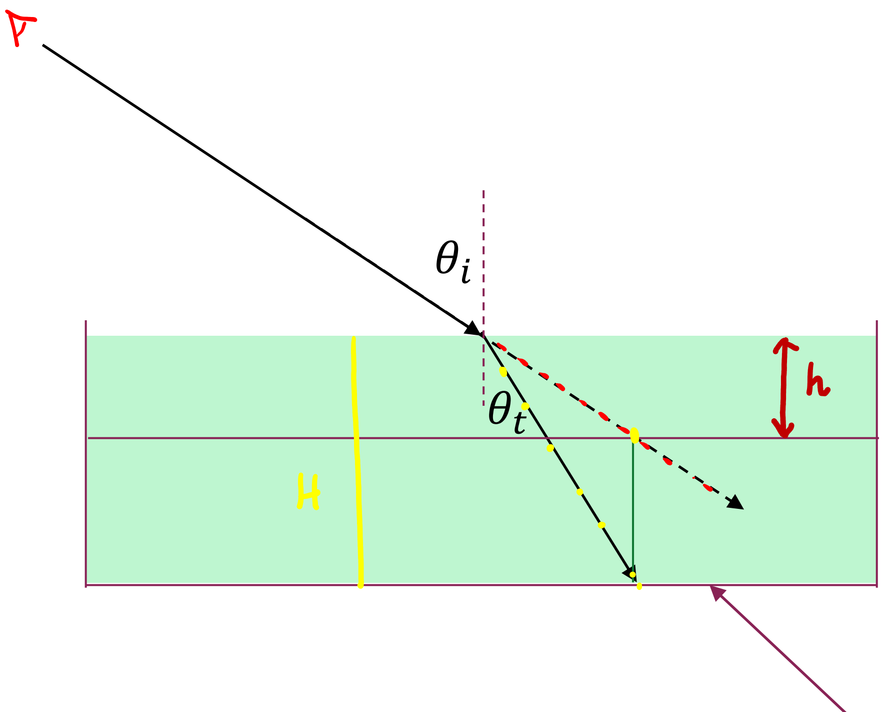
$$\theta_3 = 36.1^o$$

CONCEPTUAL QUESTIONS!

Why is the word “AMBULANCE” written like that?

Conceptual Questions!

Why does swimming pool appear shallower than its actual depth?

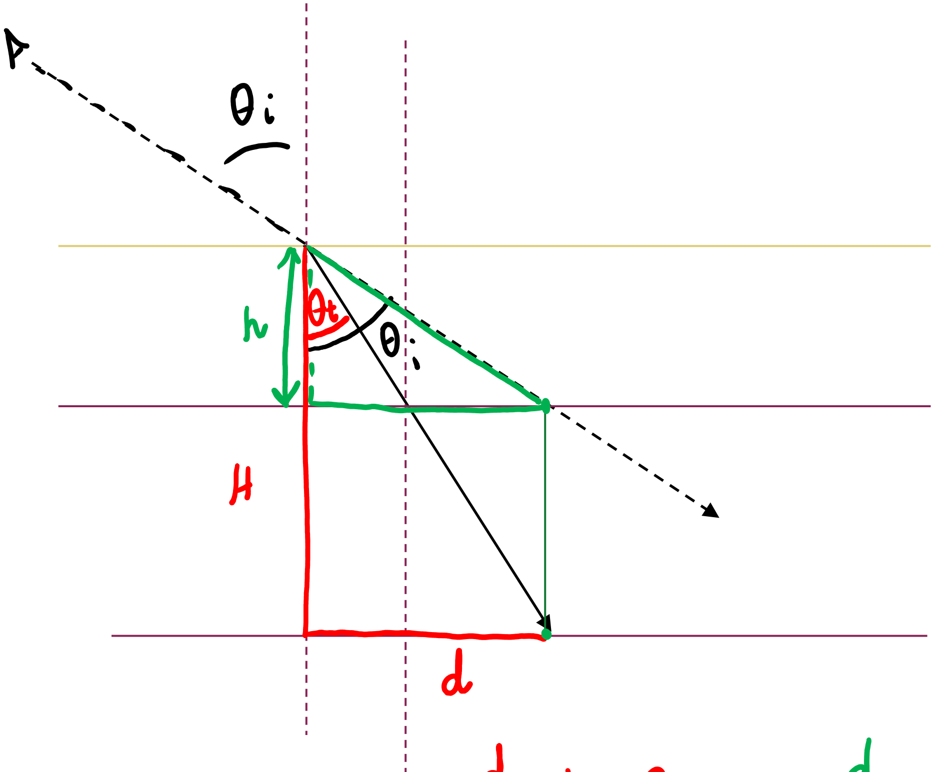


Where the bottom of the pool **appears** to be

Where the bottom of the pool is

SOLUTION!

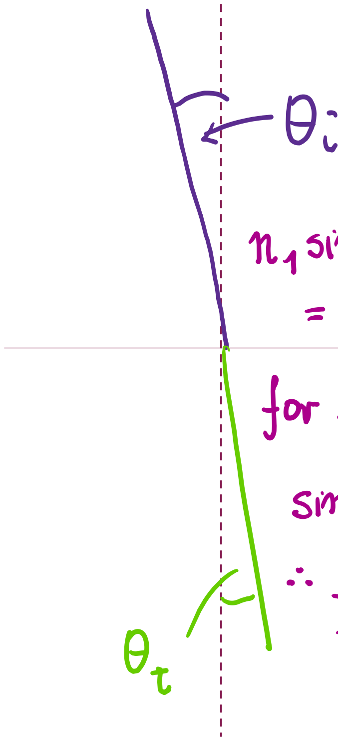
Why does swimming pool appear shallower than its actual depth?



$$\frac{d}{H} = \tan\theta_t \qquad \frac{d}{h} = \tan\theta_i$$

$$H \tan\theta_t = h \tan\theta_i \rightarrow \frac{H}{h} = \frac{\tan\theta_i}{\tan\theta_t}$$

For near-normal



$n_1 \sin\theta_i = n_2 \sin\theta_t$

for small angles

$\sin\theta \approx \tan\theta$

$\therefore \frac{\tan\theta_i}{\tan\theta_t} = \frac{n_2}{n_1}$

ZOOM POLL → March 10 learning catalytics

A pool filled with water of $n = 1.25$ appears to be 6 feet deep when viewed at the angle close to the normal to the surface

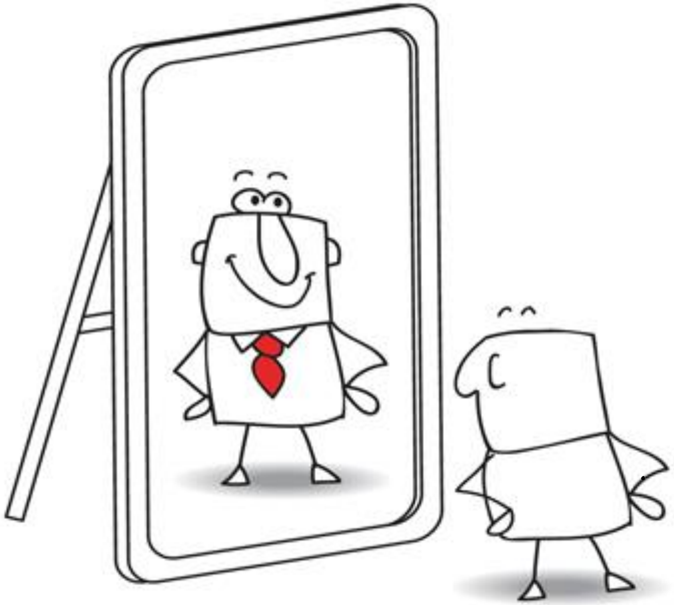
$\sin\theta \approx \tan\theta$

What is the actual depth of the pool?

a) 4.8 feet
b) 6 feet
c) 7.25 feet
d) 7.5 feet

LC! → March 10 learning catalytics

How far is the reflection?



When you are looking at your reflection in the mirror that is 0.75 m away, how far does your reflection appear to be from you?

Two-Way Mirrors

For a two-way mirror to work, the essential issue is that the room you want to look into is brighter than the room you are looking from.