Geometric Optics, Pt. I: Reflection and Refraction

Knight Secs. 34.1-34.4

Physics 2C, Spring 2025

Agenda Today (May 19 & 22, 2025)

- Reflection and Refraction: Intro
- Reflection Clicker Questions
- Refraction in Detail
  - Snell's Law
  - Total Internal Reflection
  - Image formation by Refraction (small angles)
- Thin Lenses, Introduction

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Reflection and Refraction: Definitions

Reflection: light bounces back; Refraction: light goes into different medium

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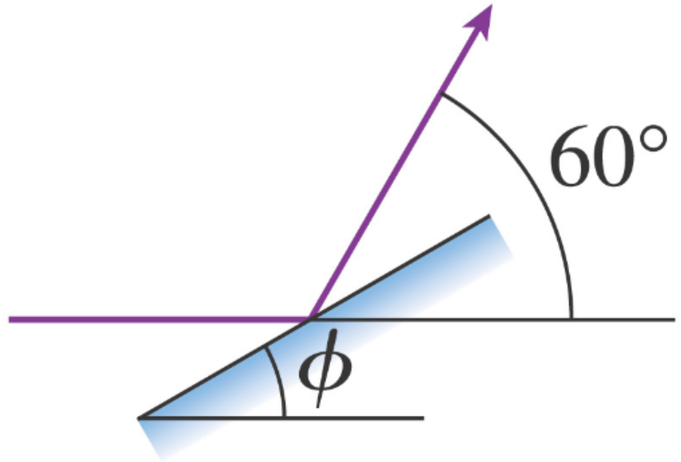
Clicker/Poll Question

The mirror in the following figure deflects a horizontal laser beam by $60°$. What is the angle ϕ?



A. $20°$

B. $30°$

C. $40°$

D. $45°$

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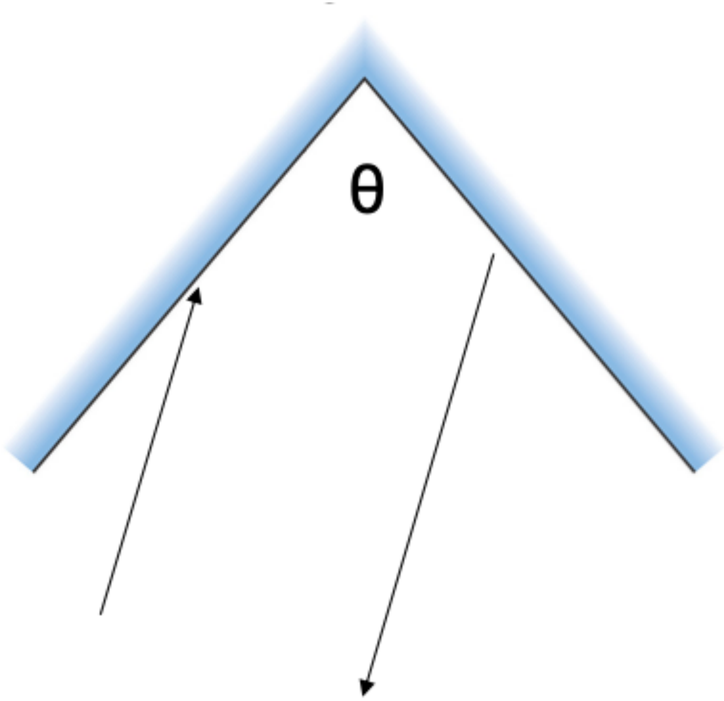
Clicker/Poll Question

A laser beam is incident on the left mirror in the following figure. If I want the reflected beam to be always parallel to the incident beam regardless of the direction of the incident beam, what should the angle θ be?



A. 45°

B. 60°

C. 90°

D. 120°

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Clicker/Poll Question

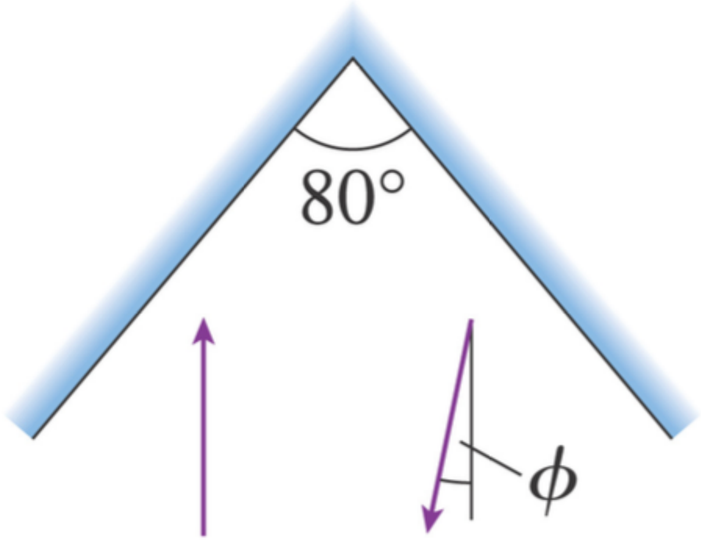
Now if θ is $80°$, what is the angle ϕ of the reflected laser beam?

A. $15°$

B. $30°$

C. $45°$

D. $20°$



Real vs. Virtual Images

Real image: light actually converges here;
Virtual image: light *appears* to come from here, but doesn’t actually

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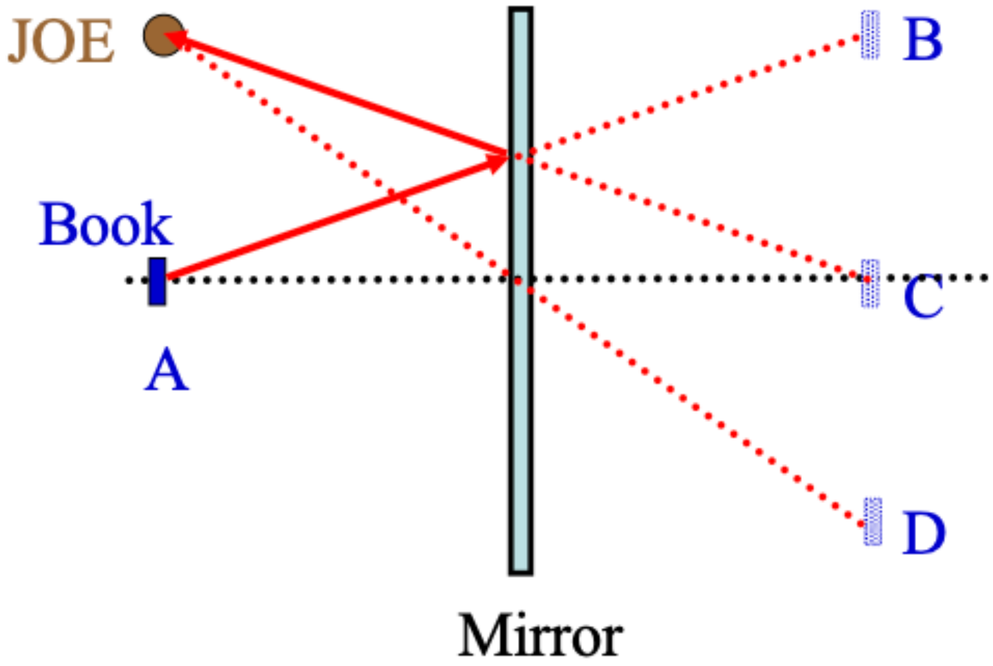
Clicker/Poll Question

Joe sees the image of a book as shown from above. Where does Joe see the image? (Joe would see the object as being at the image point if he didn't know that the mirror existed.)

A. A
B. B
C. C
D. D



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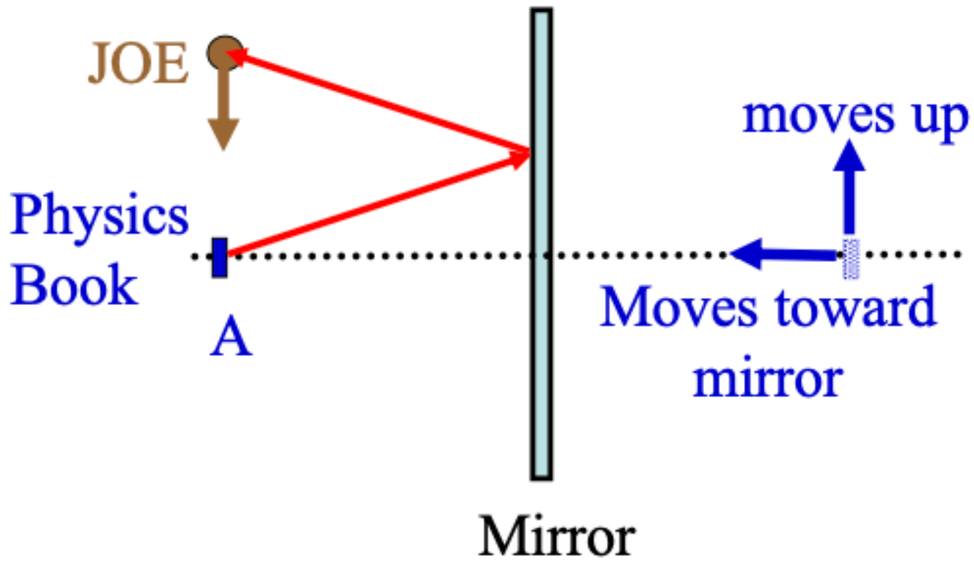
Clicker/Poll Question

Joe sees an image which is on a dotted line through the book and perpendicular to the mirror, as shown. Then, Joe moves sideways as shown by the brown arrow. Compared to its original location, the image that he sees:



A. Doesn't move.
B. Is at the same distance from the mirror but above the dotted line.
C. At the same distance but below the dotted line.
D. On the dotted line but moves toward the mirror.
E. On the dotted line but moves away from the mirror.

Example

The place you get your hair cut has two nearly parallel mirrors 5.0 m apart. As you sit in the chair, your head is 2.0 m from the nearer mirror. Looking toward this mirror, you first see your face and then, farther away, the back of your head. (The mirrors need to be slightly nonparallel for you to be able to see the back of your head, but you can treat them as parallel in this problem.)

How far away does the back of your head appear to be? Neglect the thickness of your head.

Example (continued)

Snell's Law

For Refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Clicker/Poll Question

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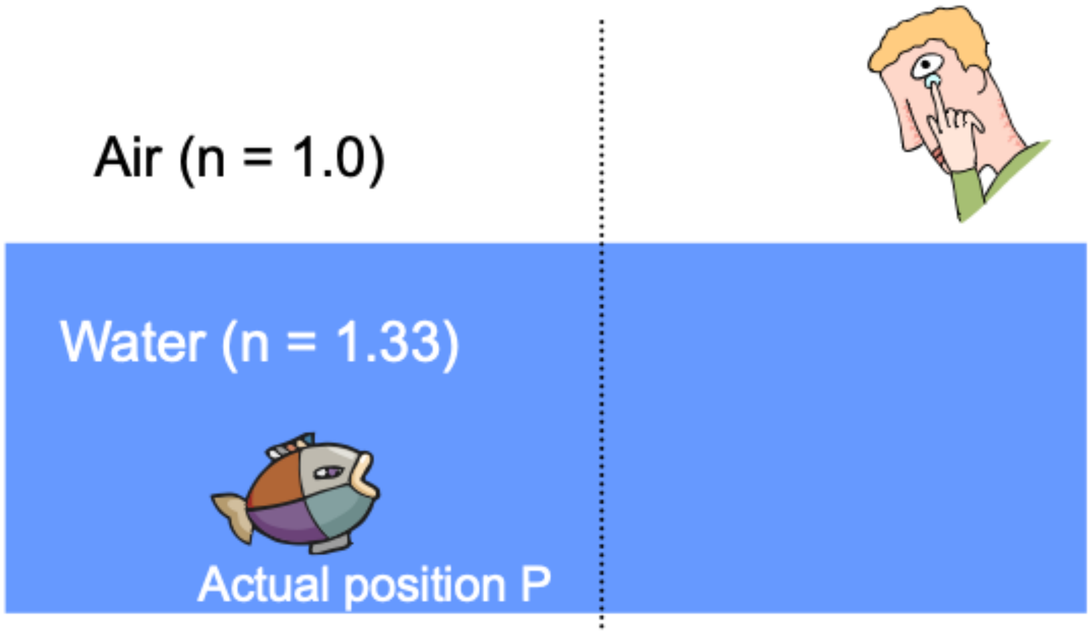
A fish swims below the surface of the water at P.

Where should a fisherman throw a spear in order to catch it?



A. Toward where he sees the fish.
B. Above where he sees the fish.
C. Below where he sees the fish.

Clicker/Poll Question

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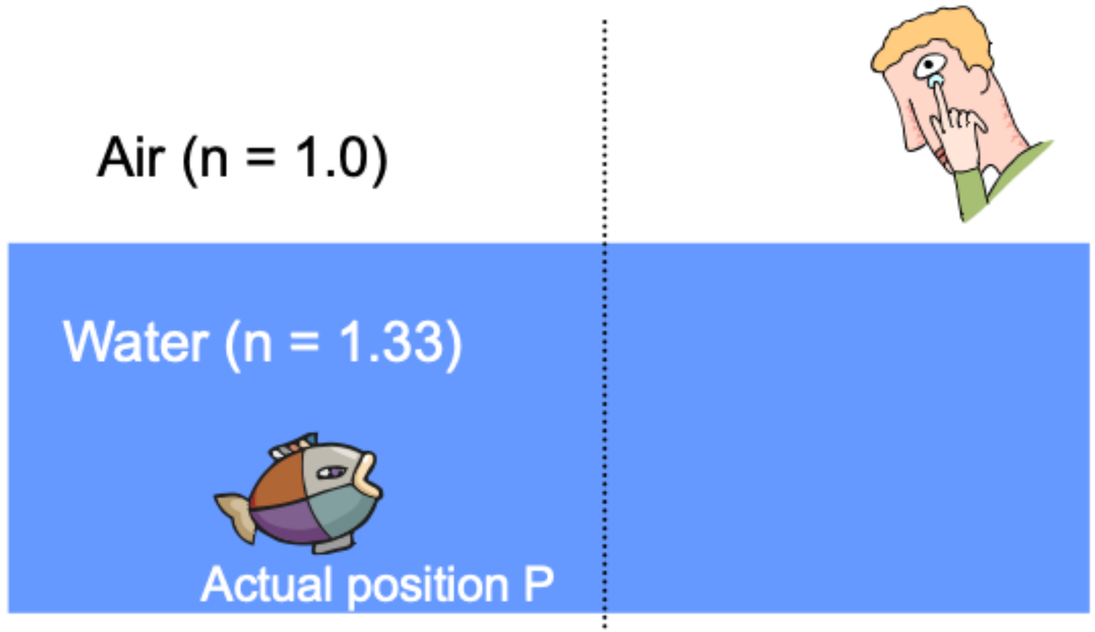
A fish swims below the surface of the water at P.

Now the fisherman decides to point a laser beam that hits the fish. What should he do?



A. Point toward where he sees the fish
B. Point above where he sees the fish
C. Point below where he sees the fish

Clicker/Poll Question

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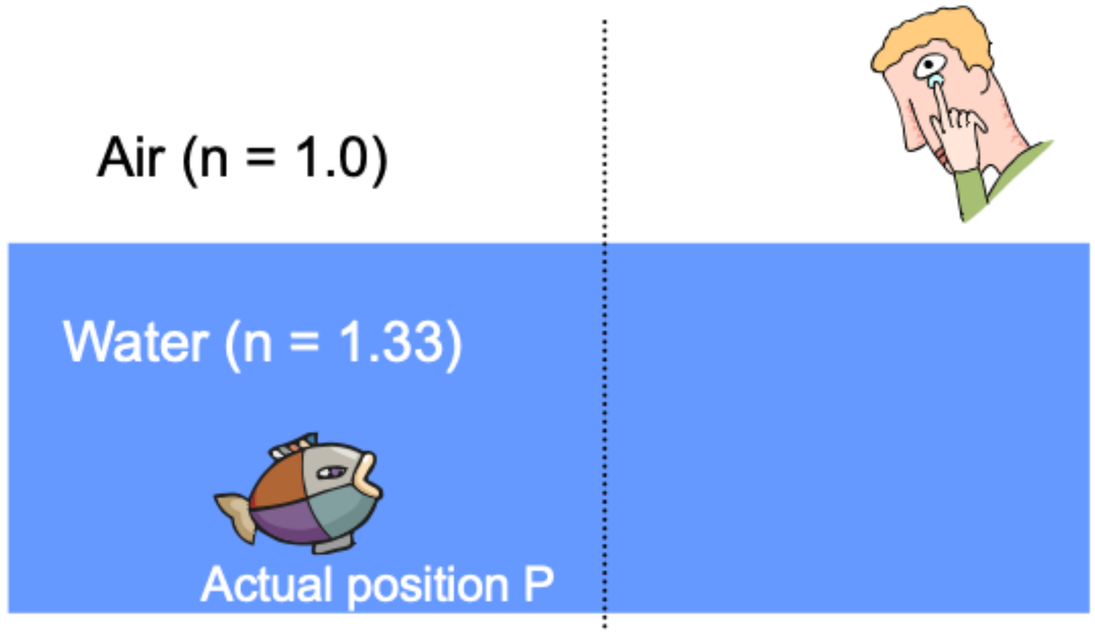
The fisherman stands above the water. A fish at P sees the fisherman's eye at

A. Exactly where it really is.
B. Above where it really is.
C. Below where it really is.



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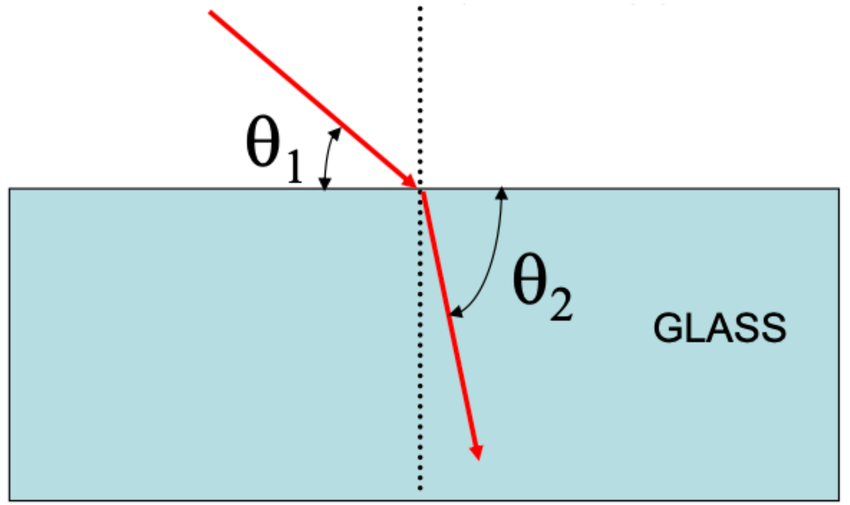
Clicker/Poll Question

Your lecturer just drew the incorrect "refraction of light" sketch for light incident from air onto a blue glass plate, as shown below. What would you suggest to make it right?



A. Make θ_2 smaller.

B. State that as drawn, $n_2 < n_1$.

C. Curve the ray in the lower medium.

D. Figure all angles from the perpendicular dotted line.

E. None of the above.

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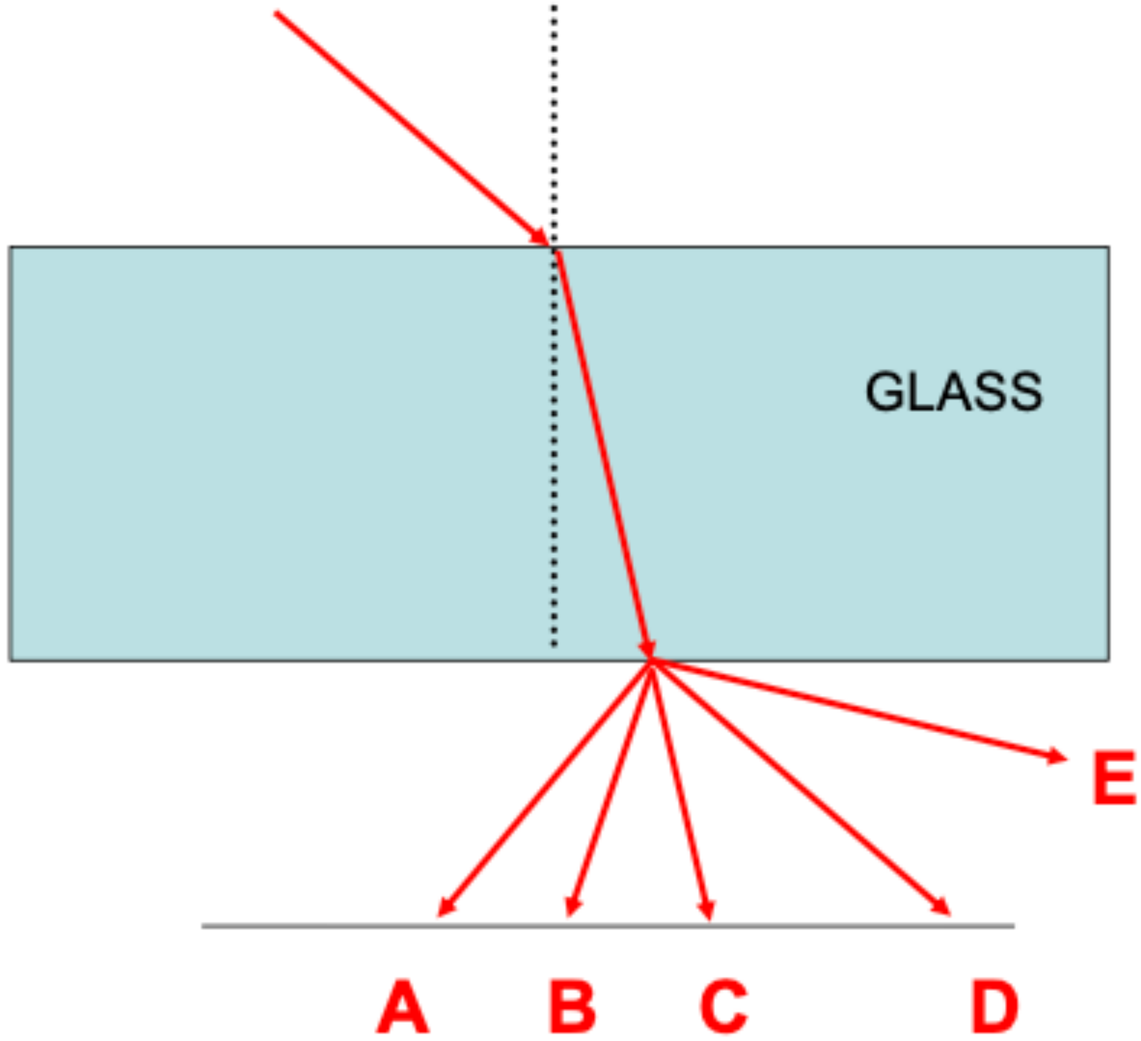
Clicker/Poll Question

The light exits the same glass plate shown in the previous sketch.

Select the direction that it will go when it exits the glass.



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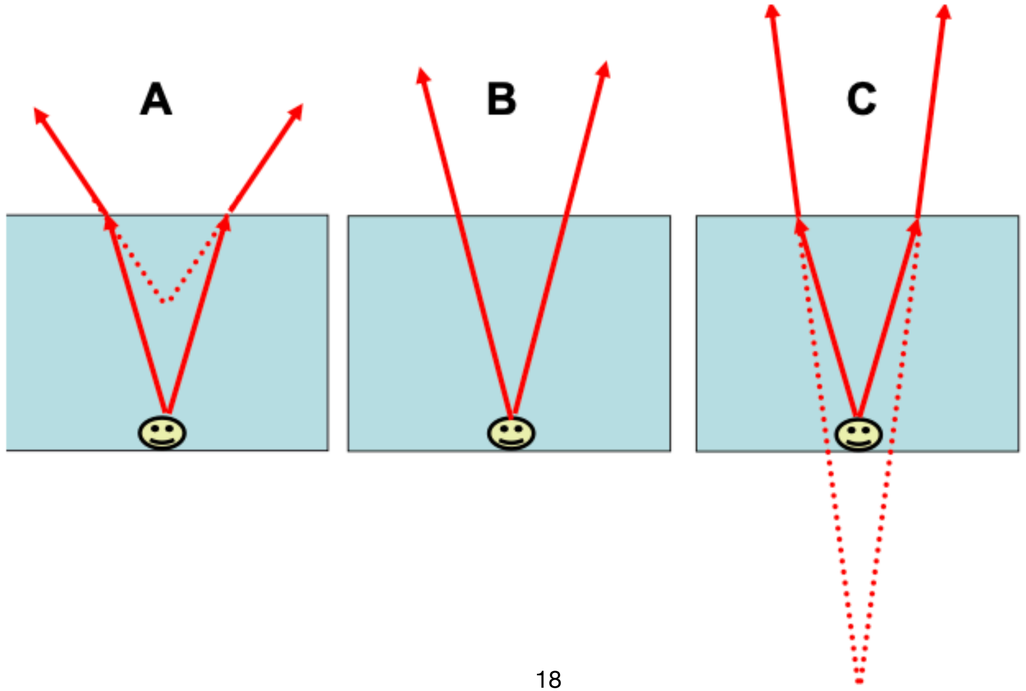
Clicker/Poll Question

Several of your friends miss retrieving a gold happy face from the bottom of a stream on their first attempt. You dazzle everyone by drawing light rays illustrating that they were reaching in the wrong place. Which of the following sketches might you have drawn?



Example

A 4.0-m-wide swimming pool is filled to the top. The bottom of the pool becomes completely shaded in the afternoon when the sun is 20° above the horizon. How deep is the pool?

Total Internal Reflection

If starting in a material with high n, it might be impossible for light to get out.

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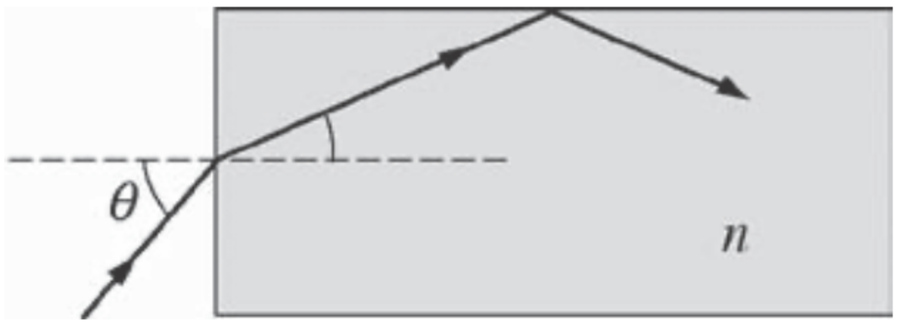
Clicker/Poll Question

A model of an optical fiber is shown in the figure below. The optical fiber has an index of refraction n and is surrounded by free space. What angles of incidence θ will result in the light staying in the optical fiber?



A. $\theta > \sin^{-1}\left(\sqrt{n^2-1}\right)$

B. $\theta < \sin^{-1}\left(\sqrt{n^2-1}\right)$

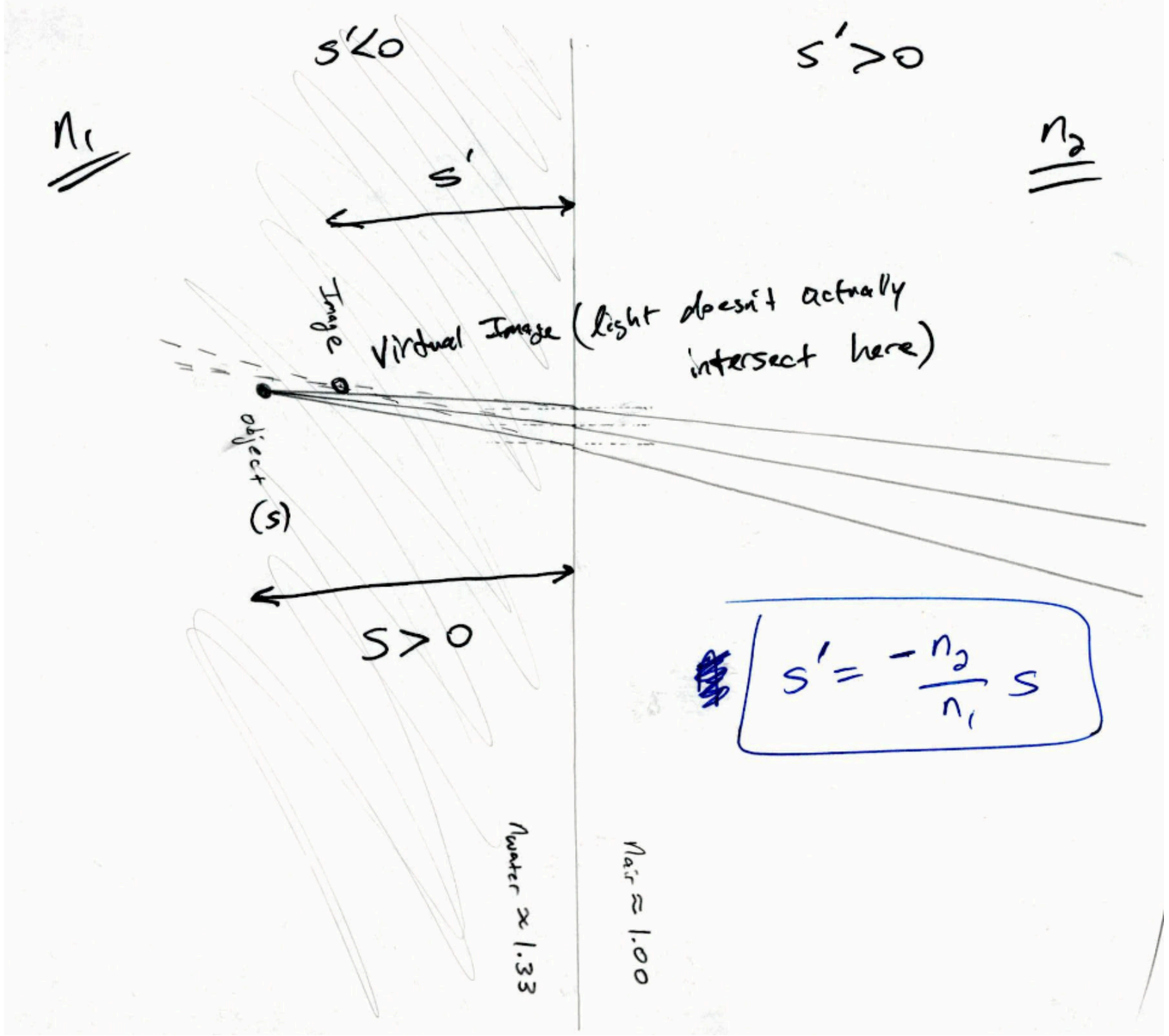
C. $\theta > \sin^{-1}\left(\sqrt{n^2+1}\right)$

D. $\theta < \sin^{-1}\left(\sqrt{n^2+1}\right)$

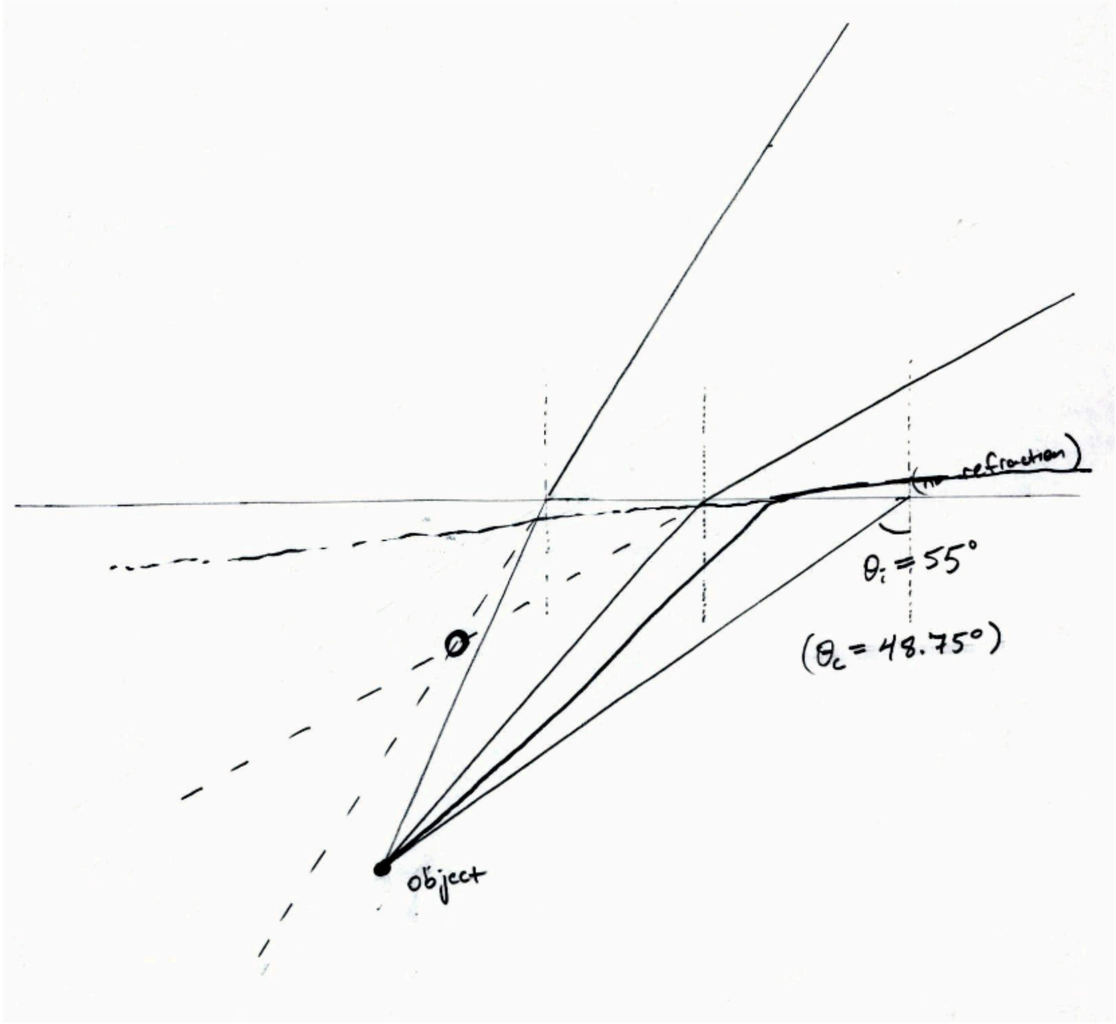
E. $\sin^{-1}\left(\sqrt{n^2-1}\right) < \theta < \sin^{-1}\left(\sqrt{n^2+1}\right)$

Image Formation by Refraction (small angles)

Objects in water are farther away than they appear!



No Image Formation by Refraction (large angles)



Try it yourself…

You're visiting the shark tank at the aquarium when you see a 2.5m-long shark that appears to be swimming straight toward you at 2.0m/s. What is the shark's actual speed through the water? You can ignore the glass wall of the tank.

More practice

It's nighttime, and you've dropped your goggles into a 3.0m-deep swimming pool. If you hold a laser pointer 1.0m above the edge of the pool, you can illuminate the goggles if the laser beam enters the water 2.0m from the edge. How far are the goggles from the edge of the pool?