SFA → SLOW TO FAST, AWAY FROM NORMAL

Physics 5041
Colleen Glover

Optics
Assignment 3: Chapter 4

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NAME: SOLUTIONS DATE: ______

Part 1

LIGHT CROSSING A BOUNDARY → CHANGE IN SPEED & CHANGE IN WAVELENGTH

1. When light passes from a more optically dense (SLOW) medium into a less optically dense (FAST) medium, it will bend AWAY FROM (towards, away from) the normal.

THE MORE OPTICALLY DENSE A MATERIAL IS, THE SLOWER THE WAVE WILL MOVE THROUGH IT.

1/2

2. When light passes from a less optically dense (FAST) medium into a more optically dense (SLOW) medium, it will bend TOWARDS (towards, away from) the normal.

FST

1/2

3. When light passes from a medium with a high index of refraction value (SLOW) into a medium with a low index of refraction value (FAST), it will bend AWAY (towards, away from) the normal.

1/2

SFA

4. When light passes from a medium with a low index of refraction value (FAST) into a medium with a high index of refraction value (SLOW), it will bend TOWARDS (towards, away from) the normal.

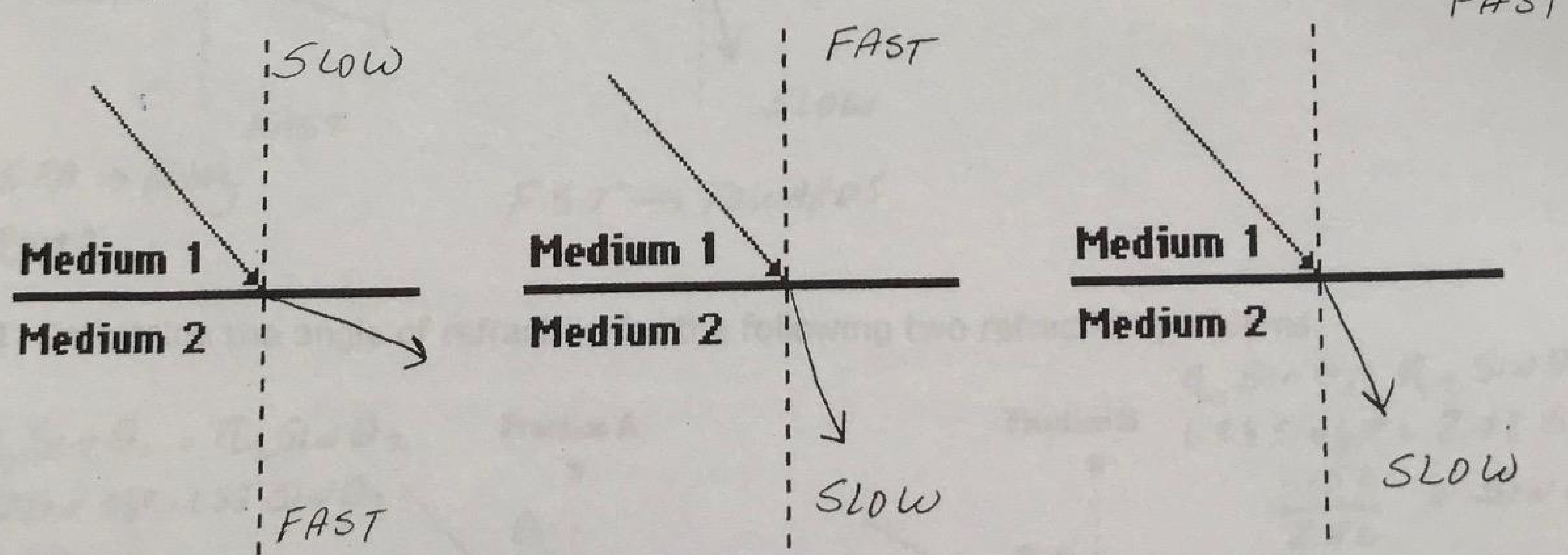
1/2

FST

5. In each diagram, draw the "missing" ray (either incident or refracted) in order to appropriately show that the direction of bending is towards or away from the normal.

1/3

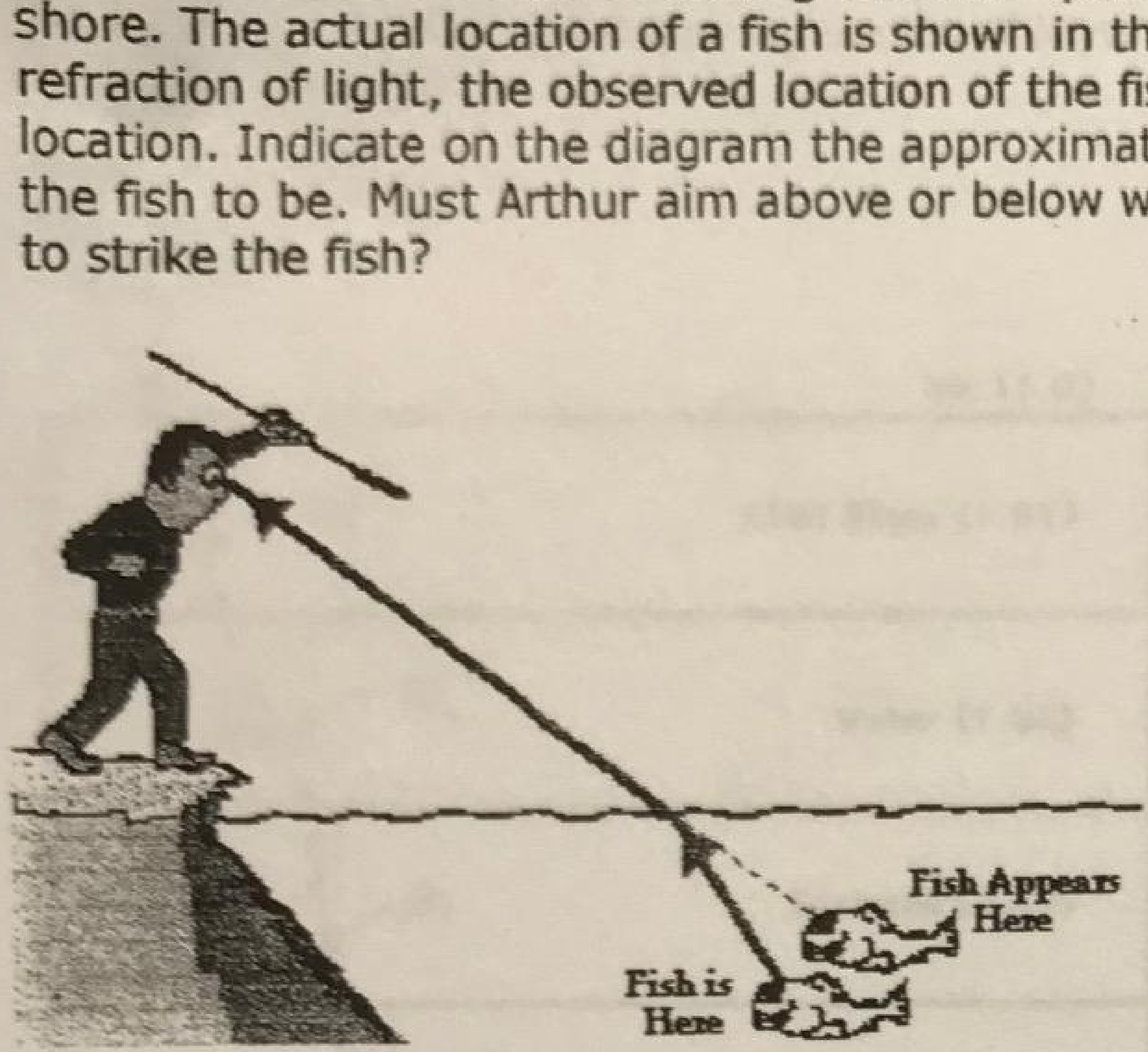
Medium 1 is more optically dense. | Medium 1 is less optically dense. | Light travels fastest in medium 1.



SFA FST FST

6. Arthur Podd's method of fishing involves spearing the fish while standing on the shore. The actual location of a fish is shown in the diagram below. Because of the refraction of light, the observed location of the fish is different than its actual location. Indicate on the diagram the approximate location where Arthur observes the fish to be. Must Arthur aim above or below where the fish appears to be in order to strike the fish?

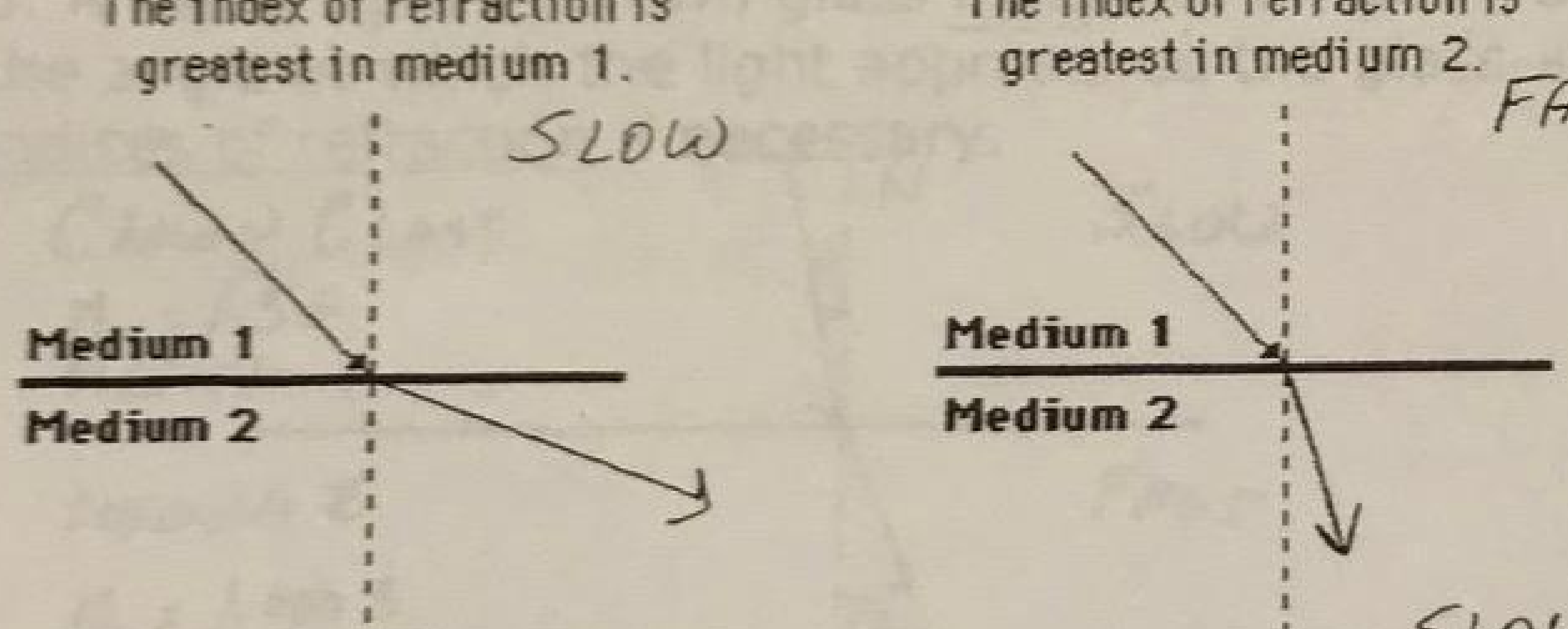
4



Arthur must aim at a position on the water below where the fish appears to be. Since light refracts away from the normal (water to air) as Arthur sights at the fish, the refracted ray when extended backwards, passes over the head of where the fish actually is.

7. For the following two cases, state whether the ray of light will bend towards or away from the normal upon crossing the boundary.

4



SFA → AWAY

FST → TOWARDS

Part 2

1. Determine the angle of refraction for the following two refraction problems.

6

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

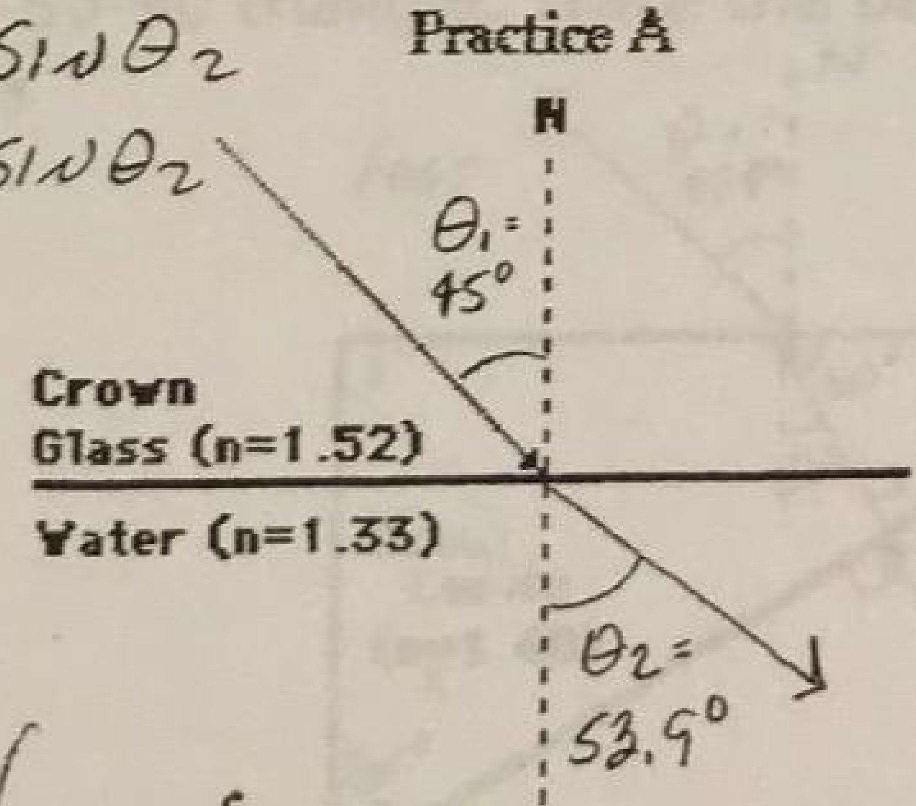
$1.52 \sin 45° = 1.33 \sin\theta_2$

$\frac{1.075}{1.33} = \sin\theta_2$

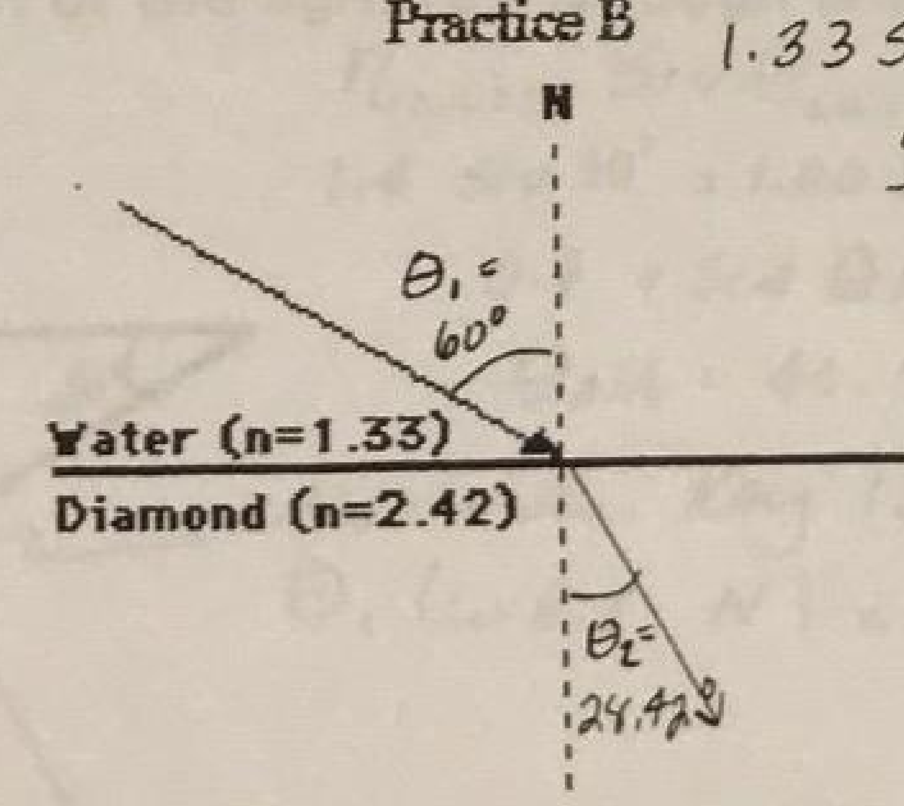
$0.808 = \sin\theta_2$

$\sin^{-1}(0.808) = \theta_2$

$\theta_2 = 53.9°$ ✓



56.7 ↑ for sin 47°



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

$1.33 \sin 60° = 2.42 \sin\theta_2$

$\frac{1.152}{2.42} = \sin\theta_2$

$0.476 = \sin\theta_2$

$\sin^{-1}(0.476) = \theta_2$

$\theta_2 = 28.42$

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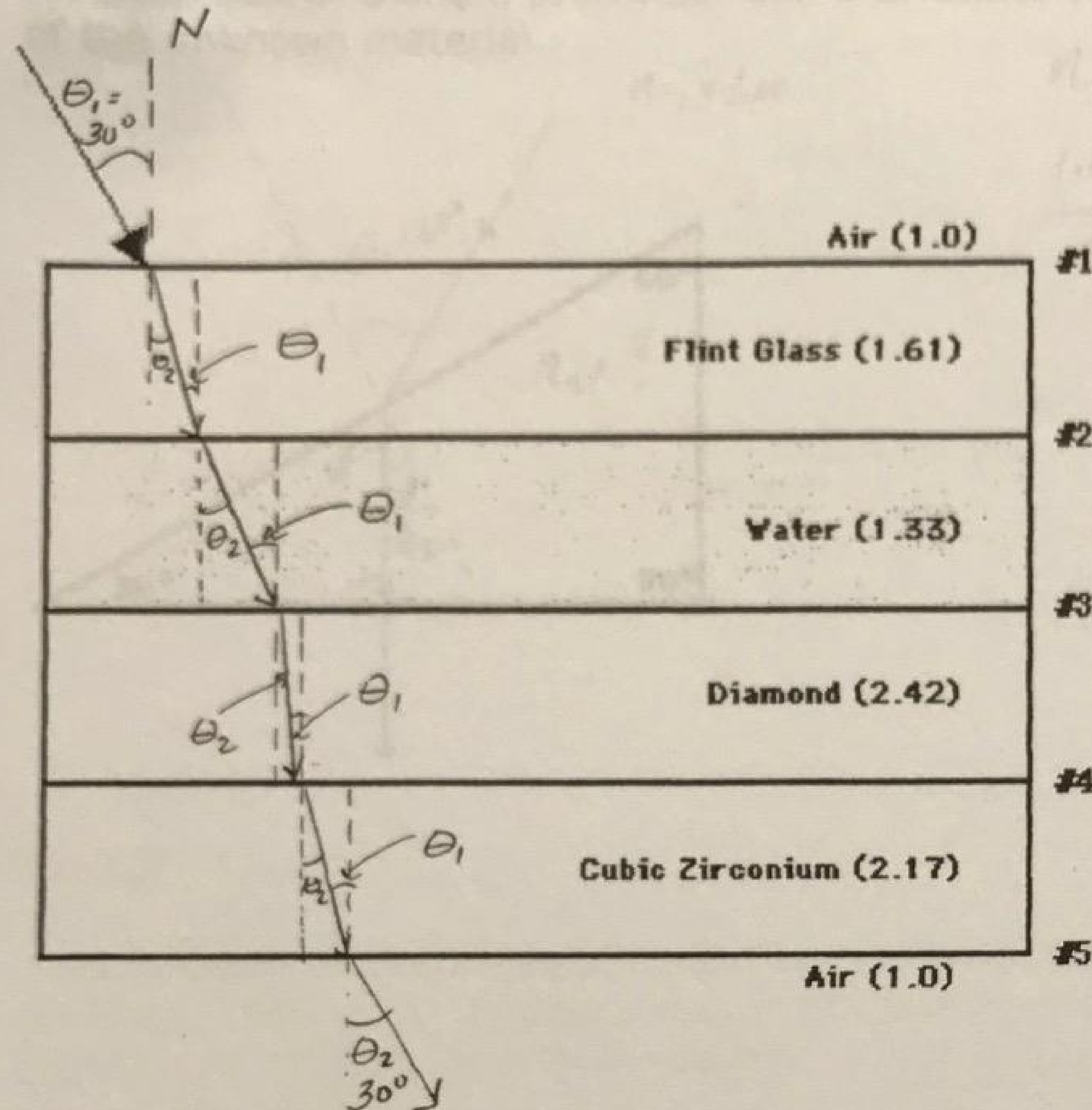
2. Perform the necessary calculations at each boundary in order to trace the path of the light ray through the following series of layers. Use a protractor and a ruler and show all your work.



$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$1.0 \sin 30 = 1.61 \sin\theta_2$
$\theta_2 = 18°$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$1.61 \sin 18 = 1.33 \sin\theta_2$
$\theta_2 = 22°$

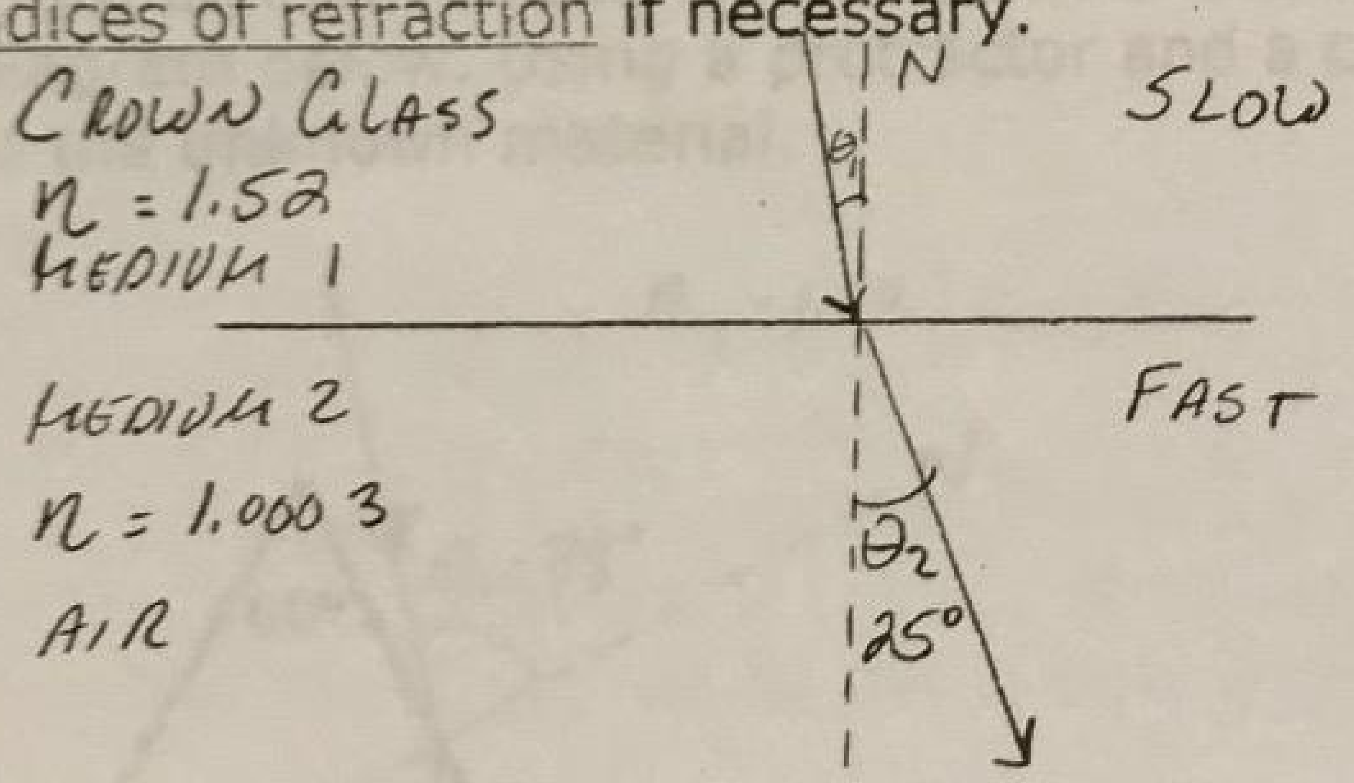
$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$1.33 \sin 22° = 2.42 \sin\theta_2$
$\theta_2 \cong 12°$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$2.42 \sin 12° = 2.17 \sin\theta_2$
$\theta_2 = 13.4°$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$2.17 \sin 13.4 = 1.0 \sin\theta_2$
$\theta_2 = 30.°$

4/4

3. A ray of light in crown glass exits into air at an angle of 25.0 degrees. Determine the angle at which the light approached the glass-air boundary. Refer to the table of indices of refraction if necessary.



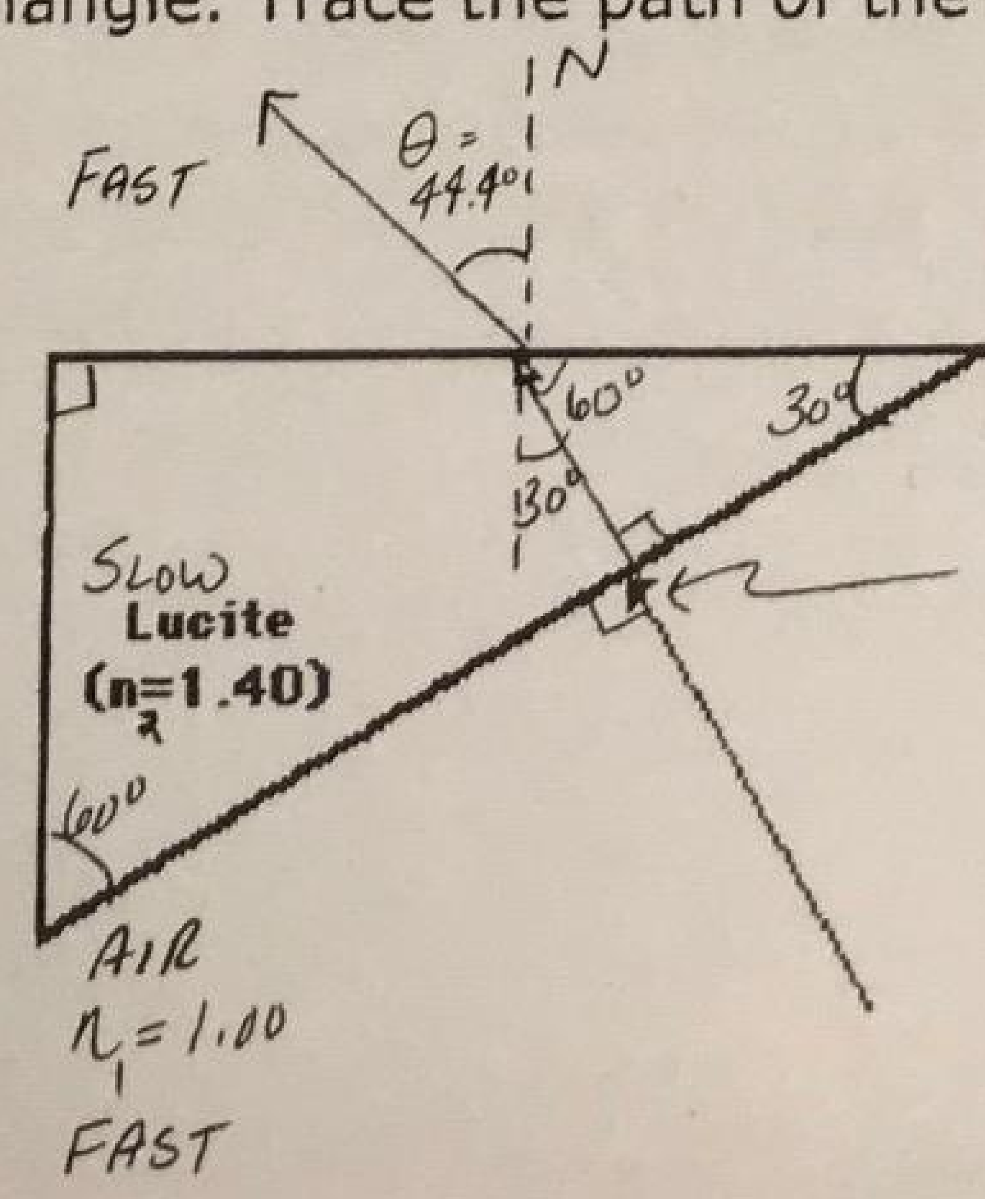
$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$1.52 \sin\theta_1 = 1.0003 \sin 25$
$\sin\theta_1 = 0.279$
$\sin^{-1}(0.279) = \theta_1 \cong 16.1°$

THIS MAKES SENSE BECAUSE IT IS CLOSER TO THE NORMAL

SFA → AWAY FROM NORMAL

4/4

4. A ray of light is traveling through air (n=1.00) towards a lucite block (n=1.40) in the shape of a 30-60-90 triangle. Trace the path of the light ray through the lucite block shown in the diagram below.

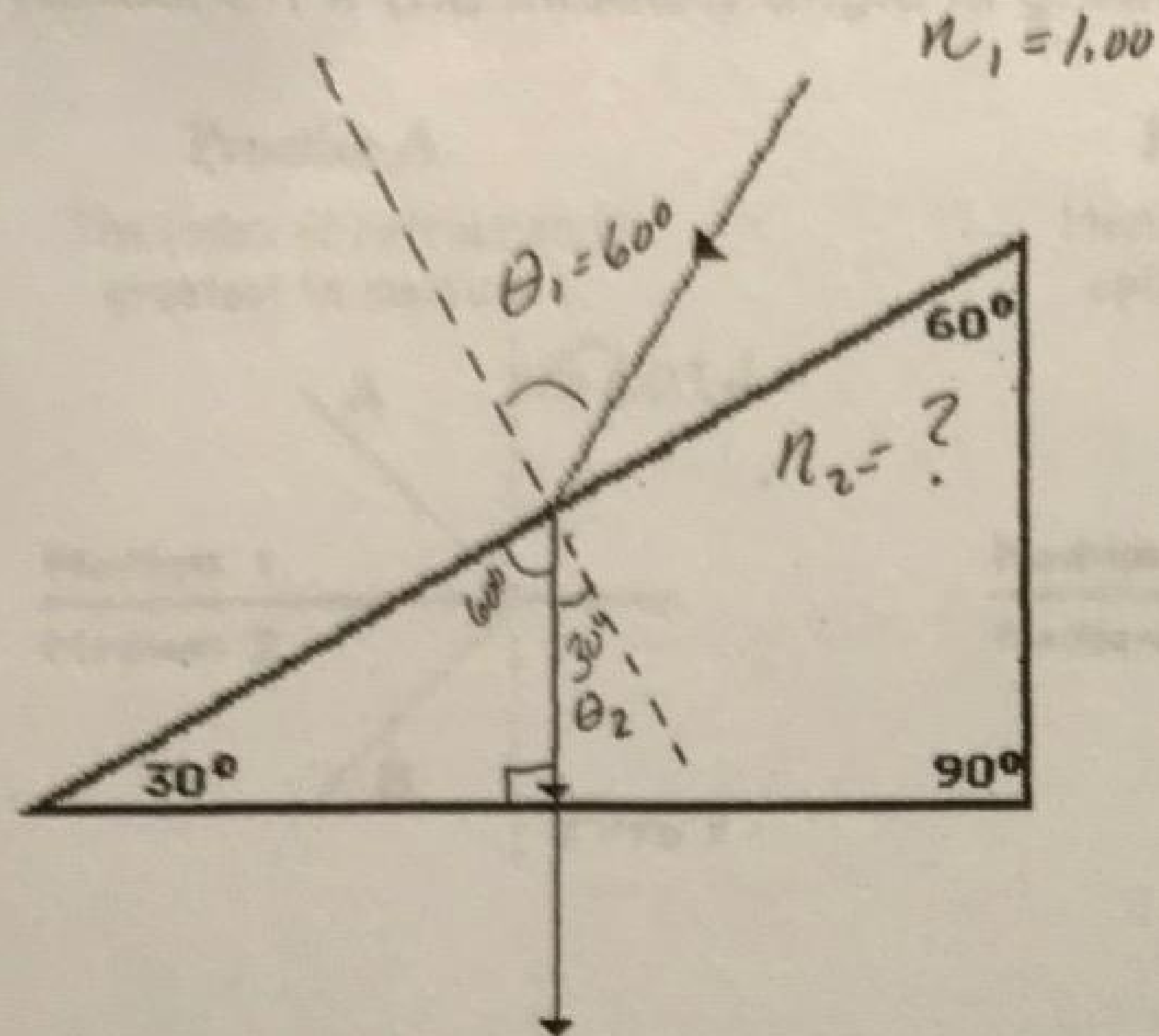


$n_{lucite} \sin\theta_{lucite} = n_{air} \sin\theta_{air}$
$1.4 \sin 30° = 1.00 \sin\theta_{air}$
$0.7 = \sin\theta_{air}$
$\theta_{air} = 44.4°$

ASSUMING RAY IS ⊥ TO SURFACE
θ_1 (W.R.T. N) = 0°

3. Light traveling through air (n = 1.00) is incident upon a triangular block made of an unknown material. The path of the light through the material is shown in the diagram below. Using a protractor and a calculator, determine the index of refraction of the unknown material.

4/4



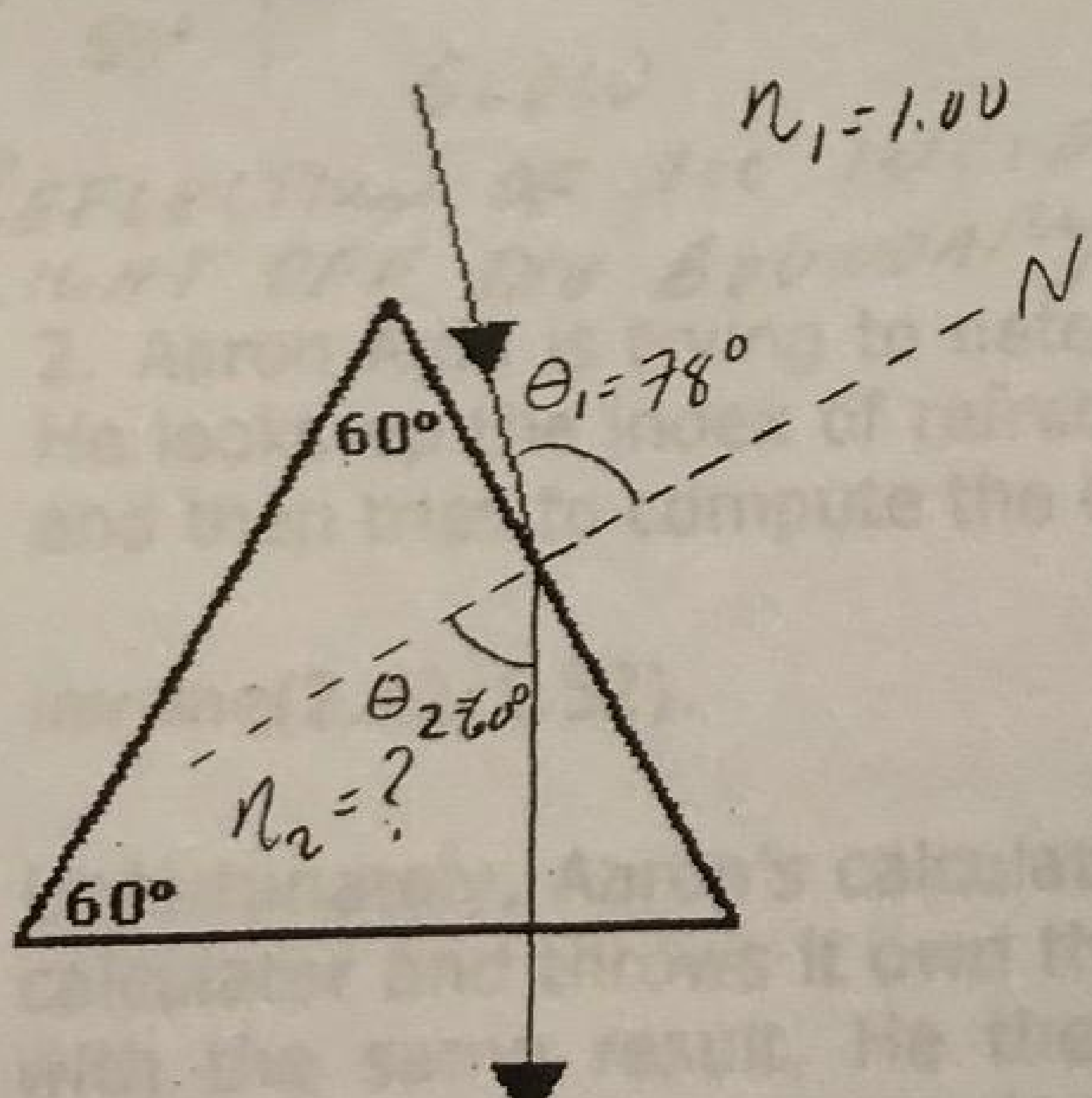
$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\frac{1.00 \sin 60°}{\sin 30°} = n_2$

$n_2 \cong 1.73$

4. Light traveling through air (n = 1.00) is incident upon a 60-60-60 triangular block (the triangle is equilateral; the sides make 60-degree angles with each other) made of an unknown material. The path of the light through the material is shown in the diagram below. Using a protractor and a calculator, determine the index of refraction of the unknown material.

4/4



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

$1.00 \sin 78° = n_2 \sin 60°$

$n_2 = 1.13$

Part 4

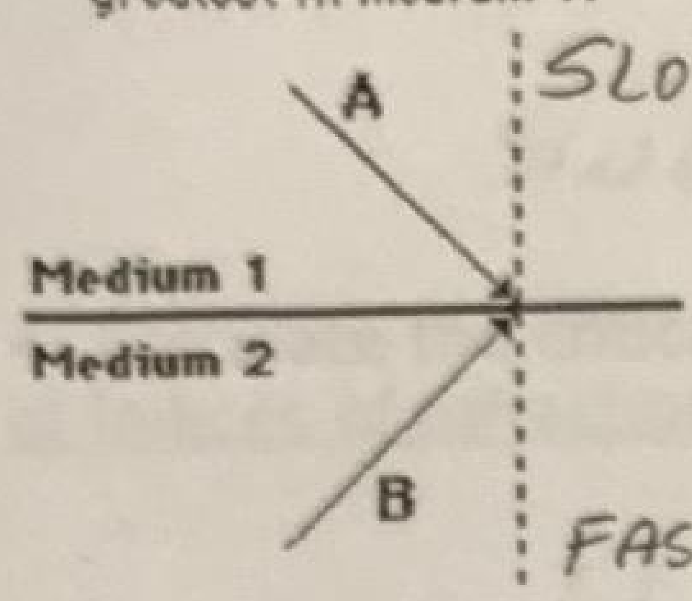
4/4

1. For each combination of media, which light ray (A or B) will undergo total internal reflection if the incident angle is gradually increased?

A WILL UNDERGO TIR BECAUSE A IS IN THE MORE OPTICALLY DENSE MEDIUM. (BOTH CASES)

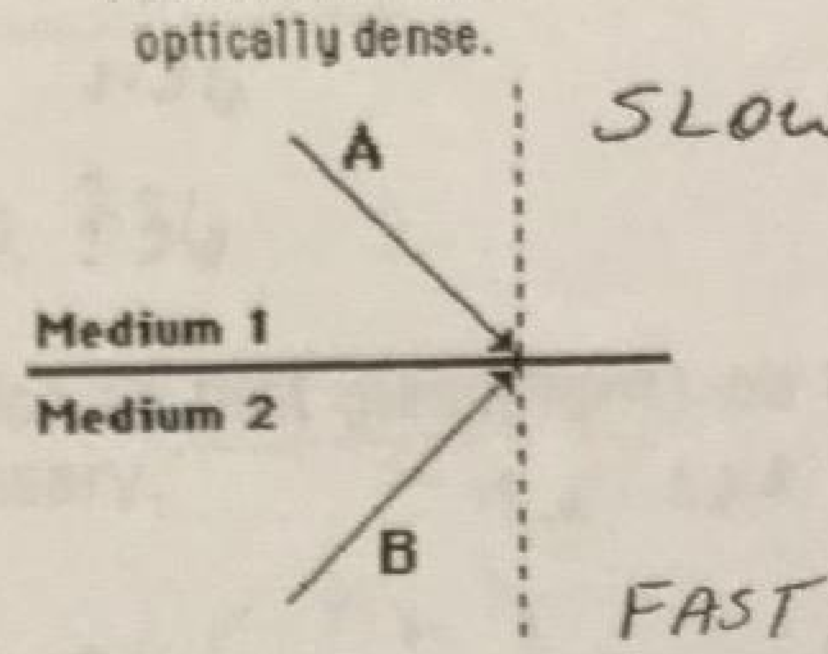
Practice A

The index of refraction is greatest in medium 1.



Practice B

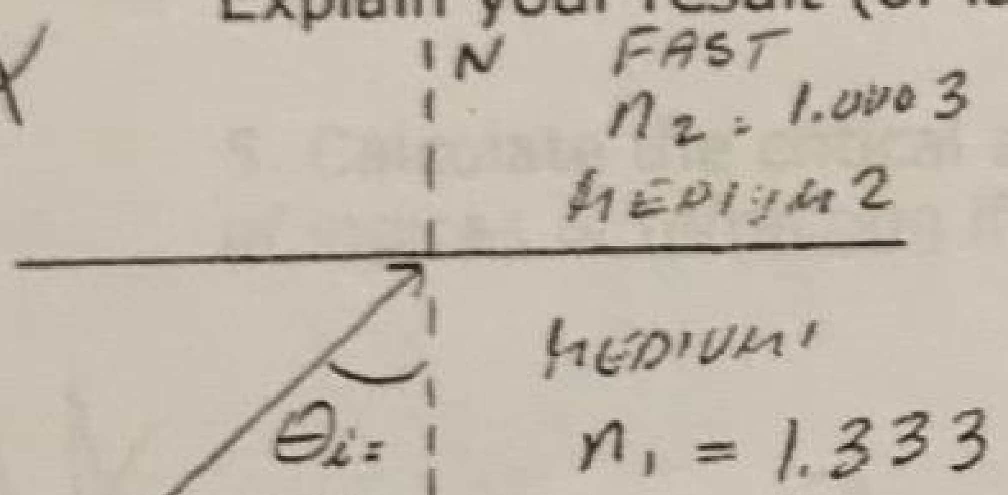
Medium 1 is more optically dense.



Part 5

4/4

1. Suppose that the angle of incidence of a laser beam in water and heading towards air is adjusted to 50-degrees. Use Snell's law to calculate the angle of refraction? Explain your result (or lack of result).



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

$\frac{1.333 \sin 50^\circ}{1.0003} = \sin\theta_2$

$1.02 = \sin\theta_2$

$\sin^{-1}(1.02) \rightarrow$ ERROR

THERE IS NO θ_r. THERE IS NO REFRACTION.

TIR: REFLECTION OF ALL INCIDENT LIGHT OFF THE BOUNDARY

2. Aaron Agin is trying to determine the critical angle of the diamond-glass surface. He looks up the index of refraction values of diamond (2.42) and crown glass (1.52) and then tries to compute the critical angle by taking the

invsine(2.42/1.52).

Unfortunately, Aaron's calculator keeps telling him he has an ERROR! Aaron hits the calculator and throws it own the ground a few times; he then repeats the calculation with the same result. He then utters something strange about the pizza he had slopped on it the evening before and runs out of the library with a disappointed disposition. What is Aaron's problem? (That is, what is the problem with his method of calculating the critical angle?)

THERE IS NO θ_r. THERE IS NO REFRACTION. THERE IS TOTAL INTERNAL REFLECTION.

$n_i = 1.36$ $n_r = 1.0003$

3. Calculate the critical angle for an ethanol-air boundary. Refer to the table of indices of refraction if necessary.

4/4

$n_i \sin \theta_i = n_r \sin \theta_r$ ← 90°

$1.36 \sin \theta_i = 1.0003 \sin 90°$

$\sin \theta_i = \frac{(1.0003)(1)}{1.36}$

$\sin \theta_i = 0.736$

$\theta_c = \sin^{-1}(0.736) = 47.35°$

$\theta_c = 47.35°$

4. Calculate the critical angle for an flint glass(light)-air boundary. Refer to the table of indices of refraction if necessary. $n_i = 1.58$

4/4

$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.0003}{1.58}\right)$

$\theta_c = 39.28°$

1.65 in book

37.30

$n_i = 2.417$

5. Calculate the critical angle for a diamond-crown glass boundary. Refer to the table of indices of refraction if necessary. $n_r = 1.52$

4/4

$\theta_c = \sin^{-1}\left(\frac{1.52}{2.417}\right)$

$\theta_c = 38.97°$

6. Some optical instruments, such as periscopes and binoculars use trigonal prisms instead of mirrors to reflect light around corners. Light typically enters perpendicular to the face of the prism, undergoes TIR off the opposite face and then exits out the third face. Why do you suppose the manufacturer prefers the use of prisms instead of mirrors?

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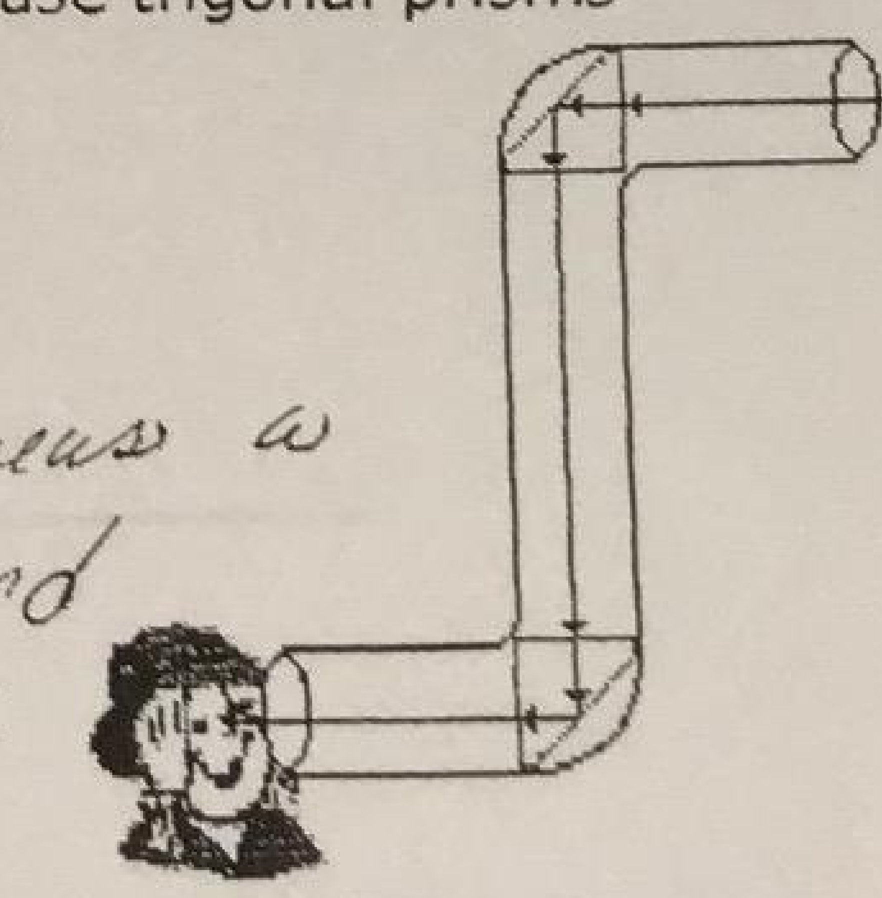
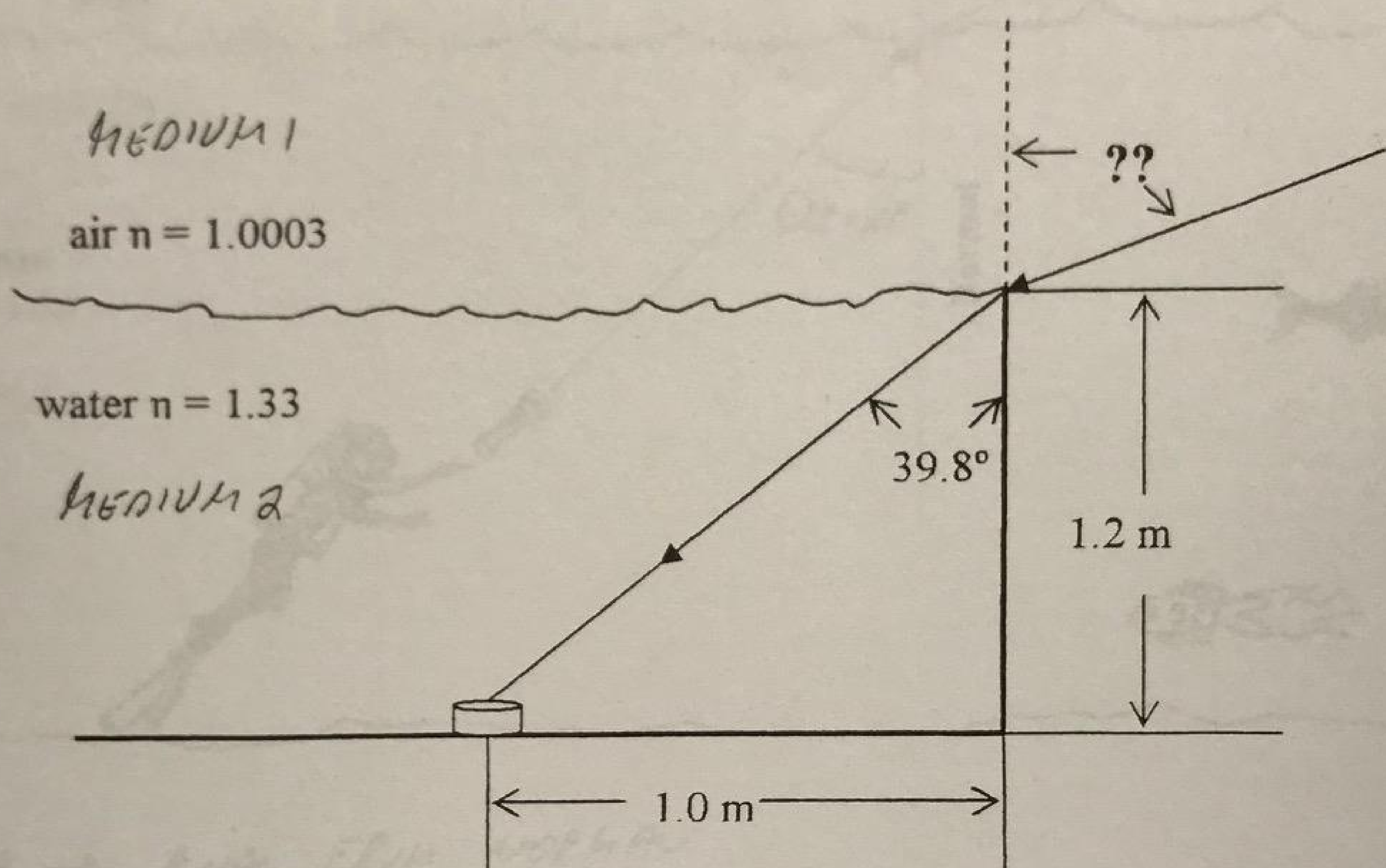


Use of trigonal prisms in a periscope.

a prism will allow light to TIR whereas a mirror allows light to both reflect and refract. So for a prism, 100% of the light is reflected, but for a mirror, only about 95% of the light is reflecting. Prism will produce a brighter image due to the greater percent of light being reflected.

4/4

7. Raphael got a little aggressive during his last street hockey game and accidentally fired the puck into his backyard swimming pool. The hockey puck lies on the bottom of the swimming pool under 1.2 m of water and 1.0 m from the edge of the pool, as illustrated. Raphael needs to find that puck before it gets stuck in the pool's drain. His flashlight beam is directed over the edge of the pool to illuminate the puck. At what angle relative to the pool wall must the flashlight be aimed? Show all calculations.



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

$1.0003 \sin\theta_1 = 1.33 \sin 39.8°$

$\sin\theta_1 = \frac{(1.33)(0.64)}{1.0003}$

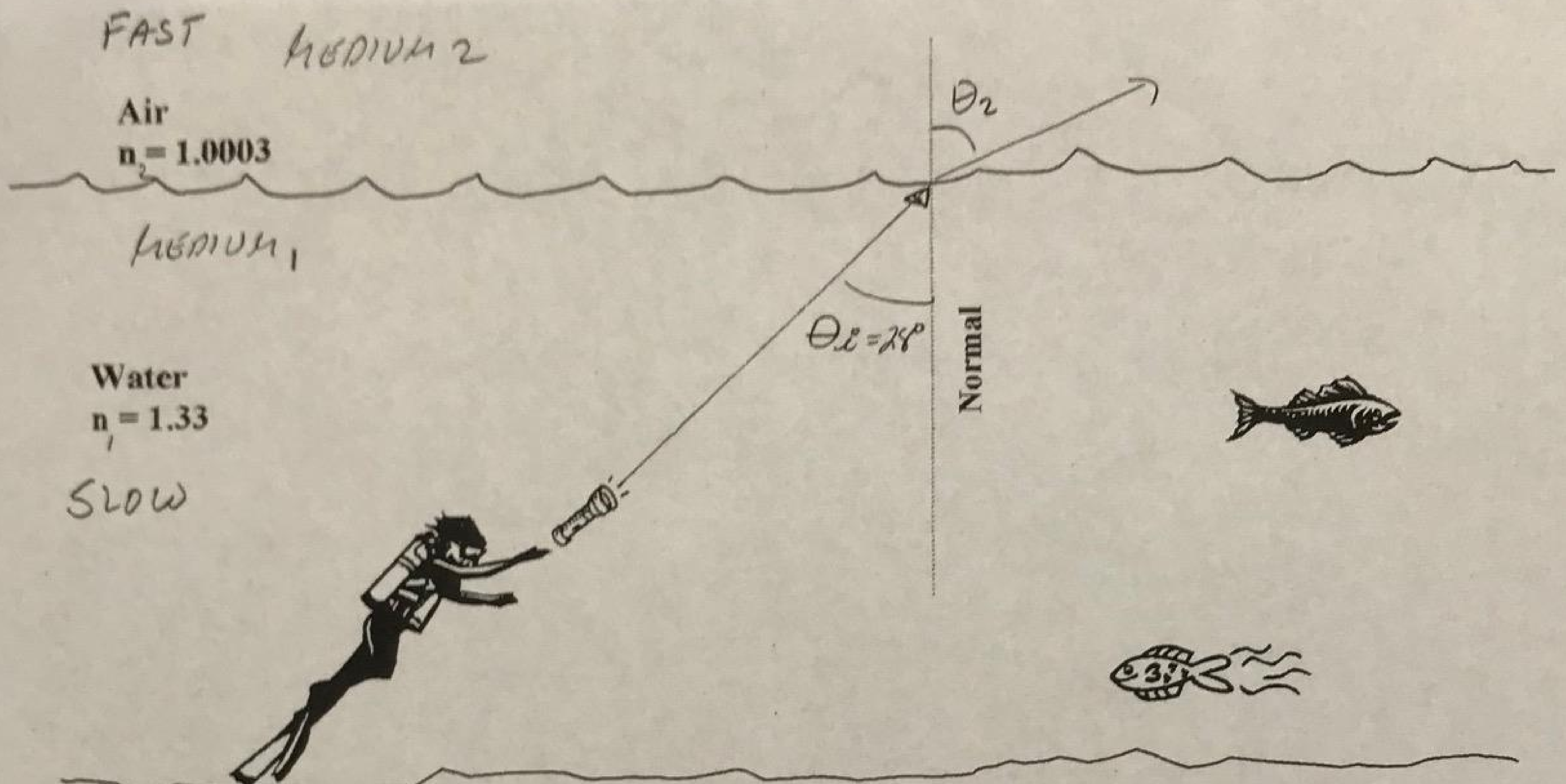
$\theta_1 = 58.31°$

ANSWER: $\theta_1 = 58.31°$

8. A scuba diver shines his laser flashlight upwards toward the surface of the water at an angle of 28° to the normal. At what angle will the laser beam emerge from the water? Show all calculations!

• DRAWING NOT TO SCALE
• FOR DEMONSTRATION ONLY

4/4



SFA → AWAY FROM NORMAL

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

$$\frac{1.33 \sin 28°}{1.0003} = \sin\theta_2$$

$$\theta_2 = 38.62°$$

ANSWER: $\theta_2 = 38.62°$