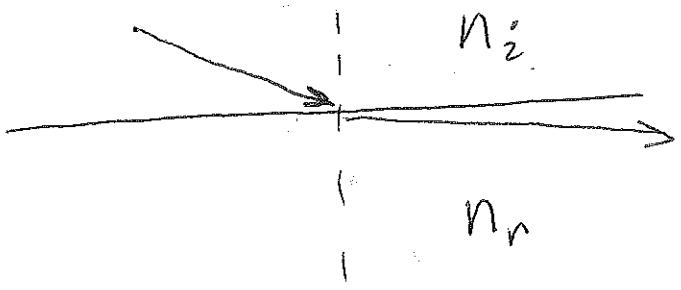
Reflection, Refraction, & Critical Angle

(1) No.



Light can bend away from the normal when $n_r < n_i$

(2) frequency stays constant
wavelength gets smaller
velocity gets smaller

$v = \lambda \cdot f$

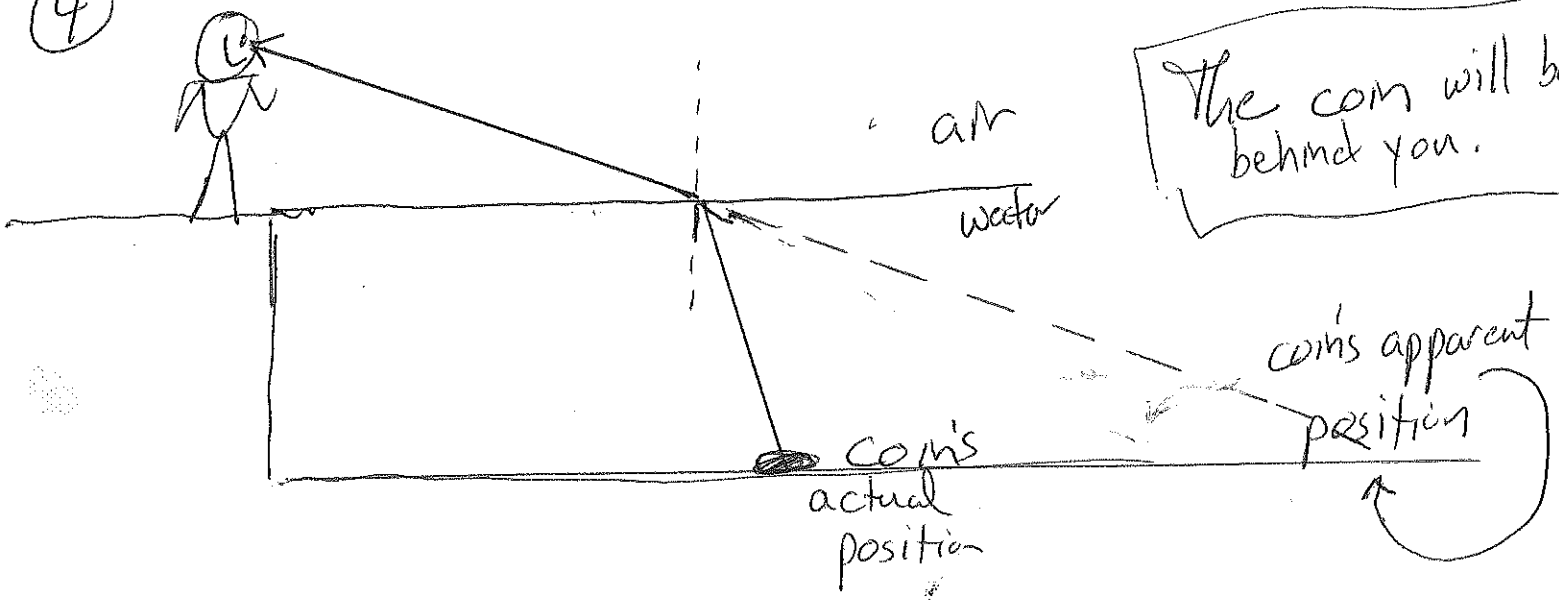
v: smaller; f: const

$\Rightarrow \lambda$ gets smaller

larger index of refraction means ~~more~~ glass is more effective at slowing light down

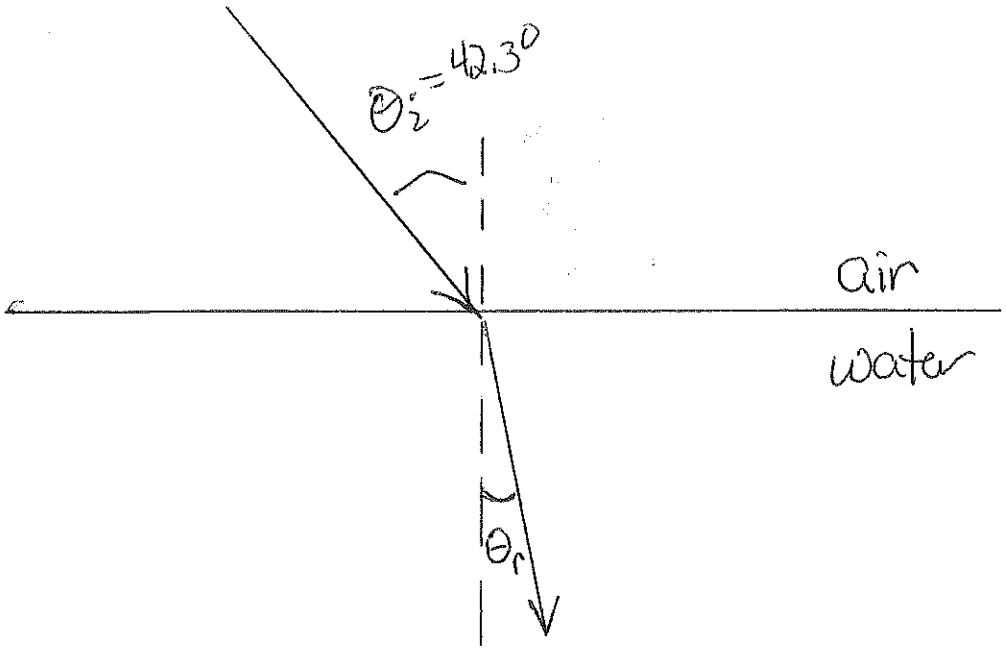
(3) X travels more slowly

(4)



The coin will be behind you.

(5)



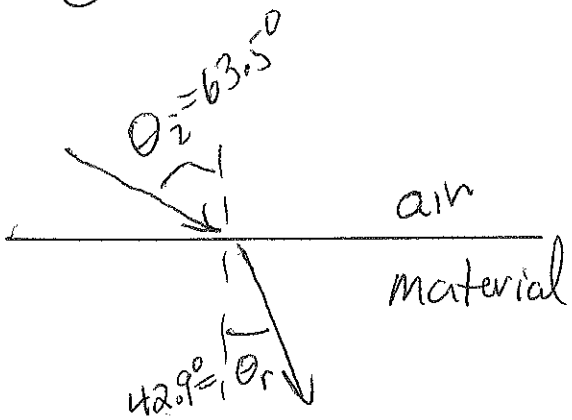
$$n_i \sin\theta_i = n_r \sin\theta_r$$

$$1.0 \sin 42.3^\circ = 1.33 \sin\theta_r$$

$$\frac{1.0}{1.33} \sin 42.3^\circ = \sin\theta_r$$

$$.506 = \sin\theta_r \Rightarrow \boxed{\theta_r = 30.4^\circ}$$

(6)



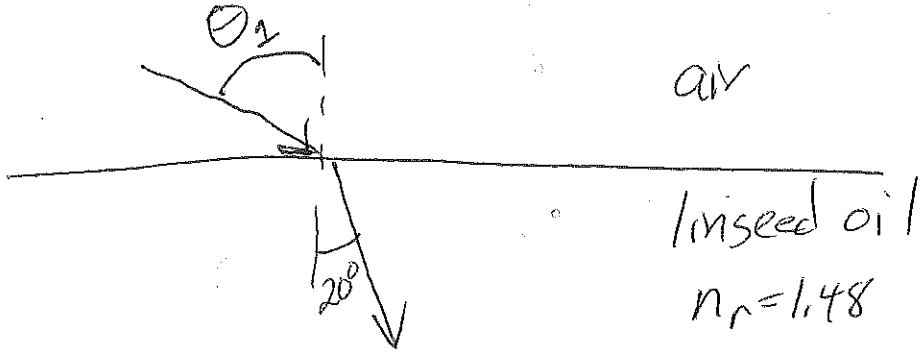
$$n_i \sin\theta_i = n_r \sin\theta_r$$

$$1.0 \sin 63.5^\circ = n_r \sin 42.9^\circ$$

$$\frac{1.0 \sin 63.5^\circ}{\sin 42.9^\circ} = n_r$$

$$\boxed{n_r = 1.31}$$

(7)

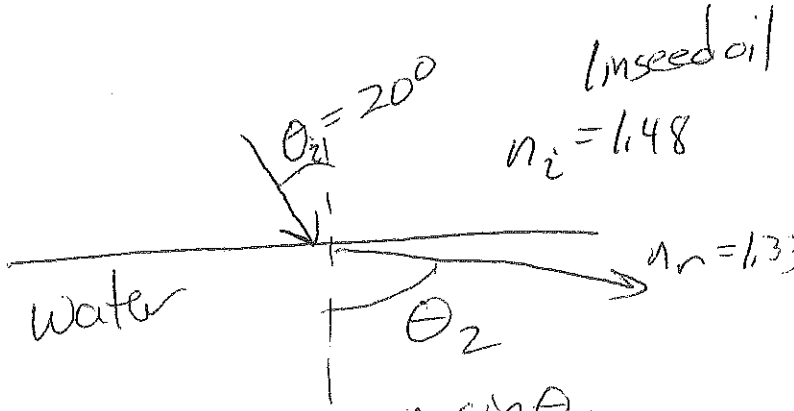


$n_i \sin\theta_i = n_r \sin\theta_r$

$1.0 \sin\theta_1 = 1.48 \sin 20°$

$\sin\theta_1 = 1.48 \sin 20°$

$\theta_1 = 30.4°$



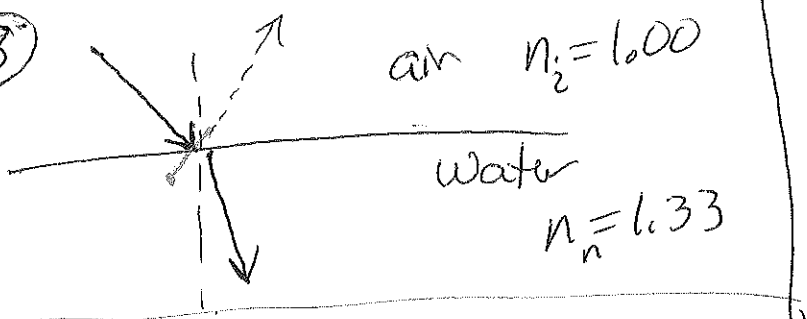
$n_i \sin\theta_i = n_r \sin\theta_r$

$1.48 \sin 20° = 1.33 \sin\theta_2$

$\frac{1.48 \sin 20°}{1.33} = \sin\theta_2$

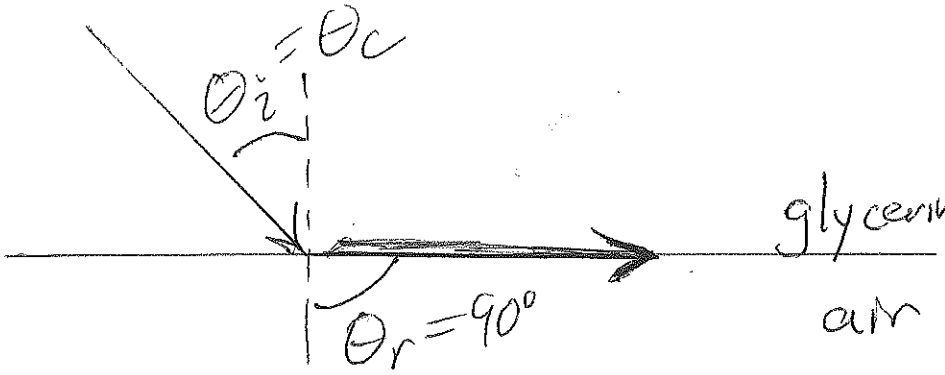
$\theta_2 = 22.4°$

(8)



No, you only get total internal reflection when $n_i > n_r$.

(9)



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

$$1.473 \sin\theta_c = 1.0 \sin 90°$$

$$\sin\theta_c = \frac{1}{1.473}$$

$$\theta_c = 42.8°$$

Method 1

Find the critical angle by assuming $\theta_r = 90°$.

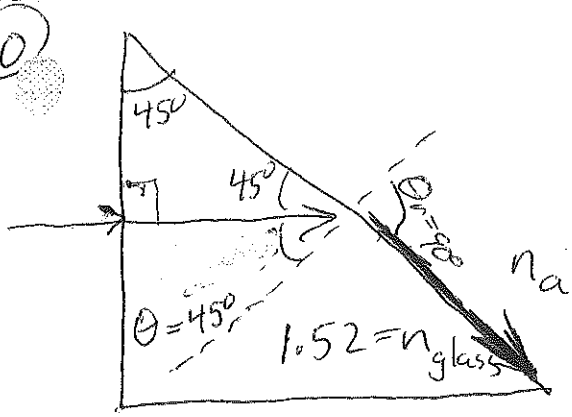
$$n_i \sin\theta_i = n_r \sin\theta_r$$

$$1.52 \sin\theta_c = 1.0 \sin 90°$$

$$\sin\theta_c = \frac{1.0 \sin 90°}{1.52} = \frac{1}{1.52}$$

$\theta_c = 41° \Rightarrow$ This is the critical angle.

(10)



alternative method

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

$$1.52 \sin 45° = 1.0 \sin\theta_r$$

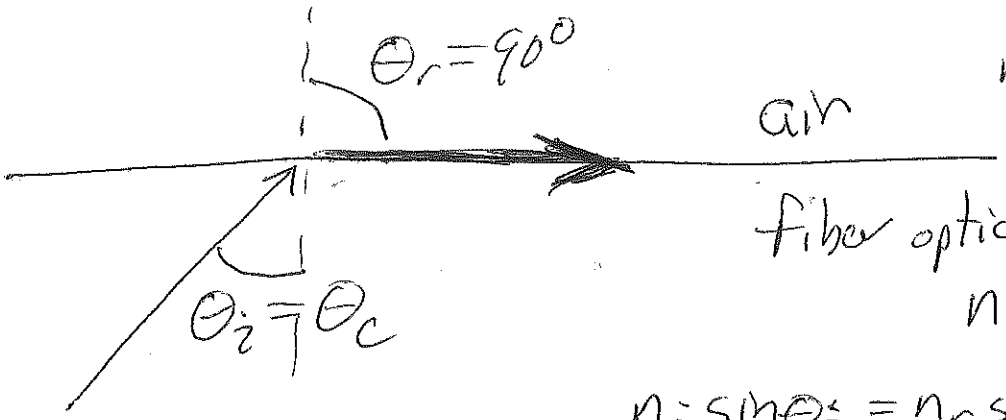
$$\frac{1.52 \sin 45°}{1} = \sin\theta_r$$

$$1.07 = \sin\theta_r$$

No θ's have sines larger than 1 $\Rightarrow$ must not be a refracted ray $\Rightarrow$ total internal reflection

Since the incident angle is 45° we are beyond the critical angle (41°) & there will be total internal reflection.

(11)



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

$$1.53 \sin\theta_c = 1.00 \sin 90^\circ$$

$$\sin\theta_c = \frac{1}{1.53}$$

(a) $\boxed{\theta_c = 40.8^\circ}$

(b) for water

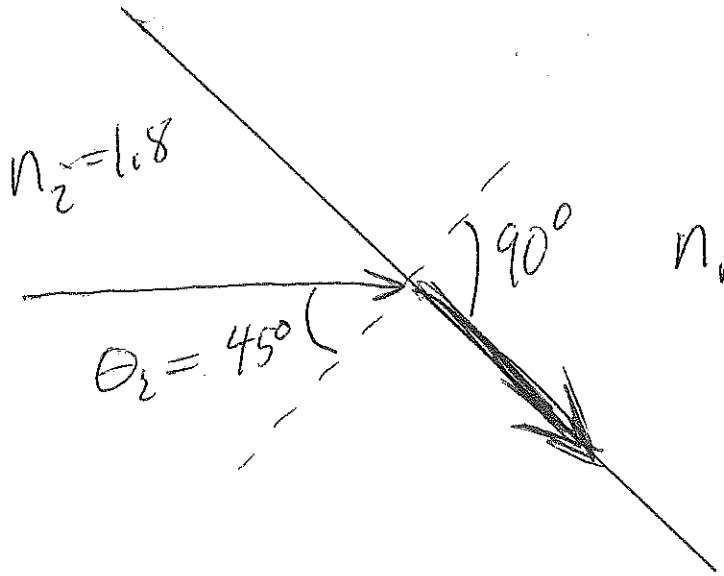
$$n_i \sin\theta_i = n_r \sin\theta_r$$

$$1.53 \sin\theta_c = 1.33 \sin 90^\circ$$

$$\sin\theta_c = \frac{1.33}{1.53}$$

$$\boxed{\theta_c = 60.4^\circ}$$

(12)



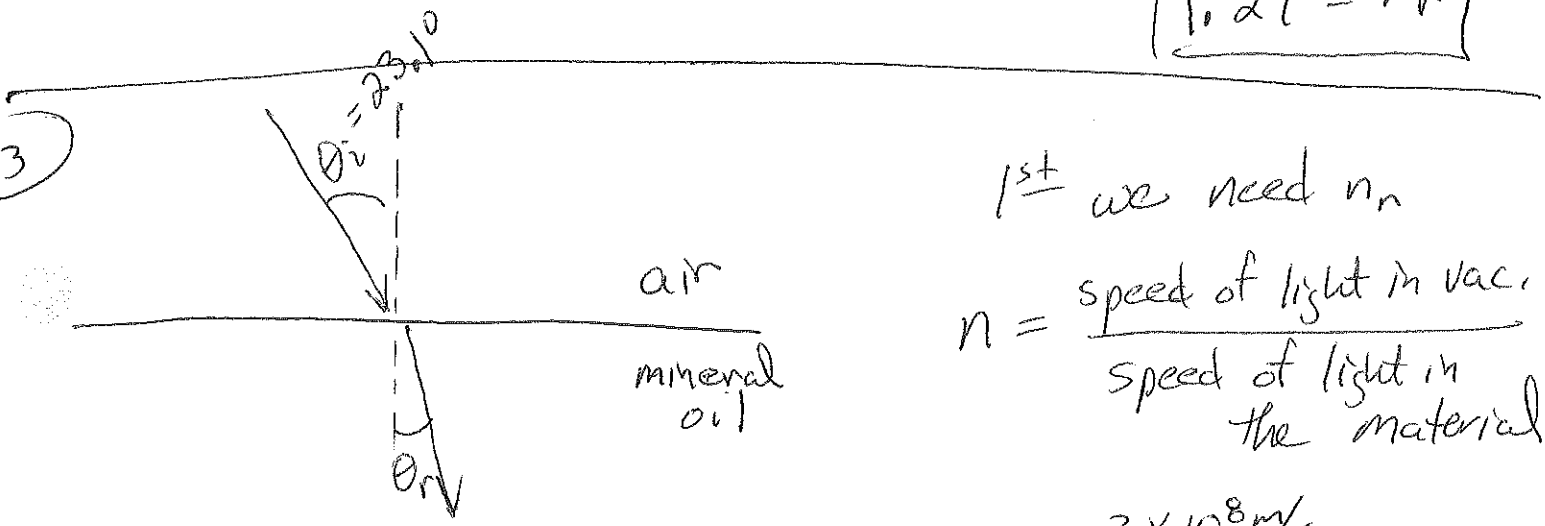
$n_i \sin\theta_i = n_r \sin\theta_r$

$1.8 \sin 45° = n_r \sin 90°$

$\frac{1.8 \sin 45°}{\sin 90°} = n_r$

$\boxed{1.27 = n_r}$

(13)



1st we need n_r

$n = \frac{\text{speed of light in vac.}}{\text{speed of light in the material}}$

$n = \frac{3 \times 10^8 m/s}{2.17 \times 10^8 m/s}$

$n = 1.38$

2nd

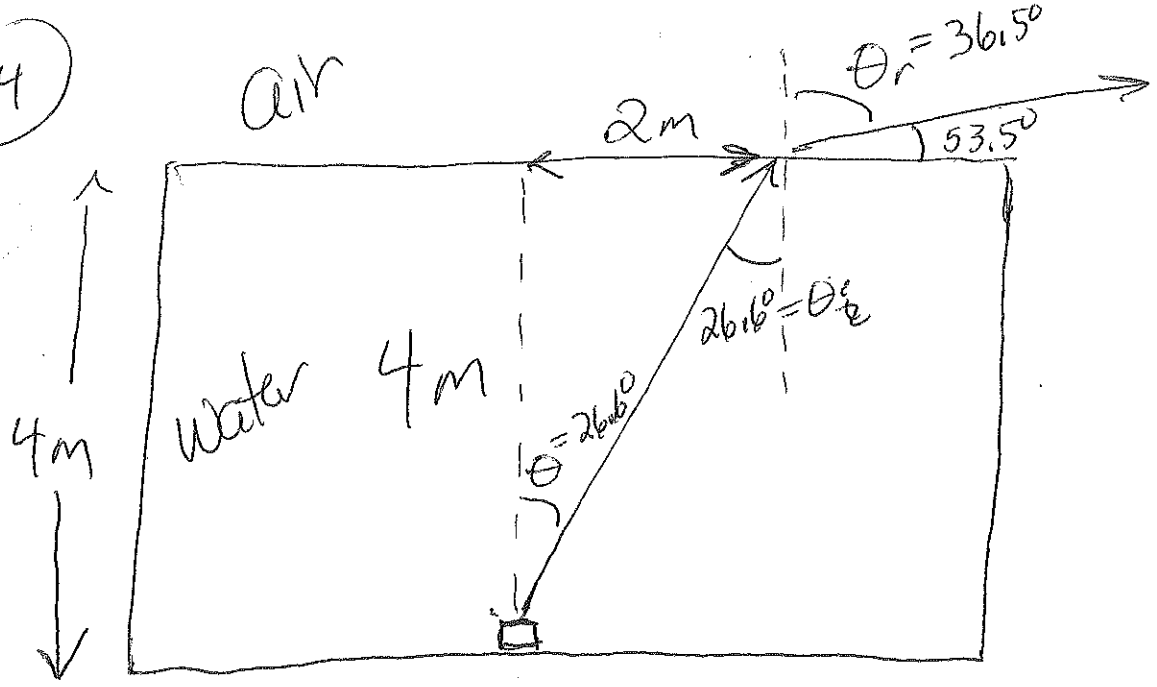
$n_i \sin\theta_i = n_r \sin\theta_r$

$1.0 \sin 23.1° = 1.38 \sin\theta_r$

$\frac{\sin 23.1°}{1.38} = \sin\theta_r$

$\boxed{\theta_r = 16.5°}$

(14)



$$\tan\theta = \frac{2}{4}$$

$$\theta = 26.6°$$

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

$$1.33 \sin 26.6° = 1.0 \sin\theta_r$$

$$\theta_r = 36.5°$$

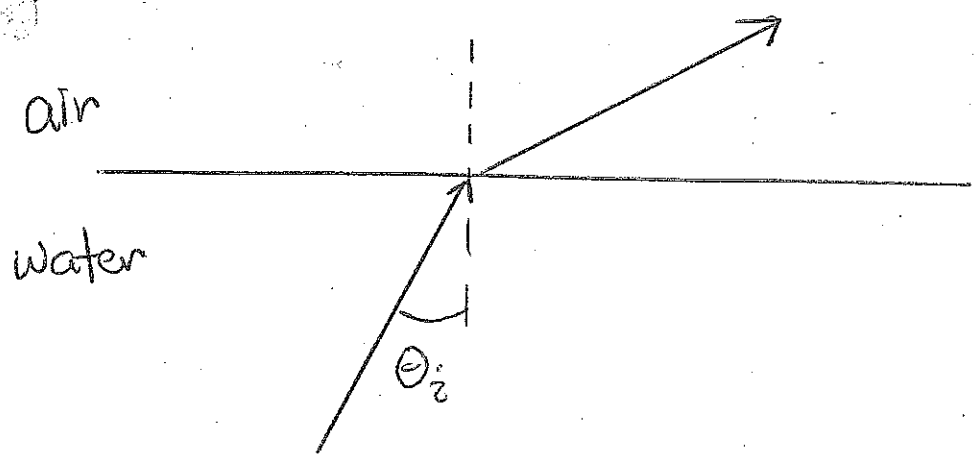
$$90° - 36.5° = \boxed{53.5°}$$

with the pool's surface

(A)

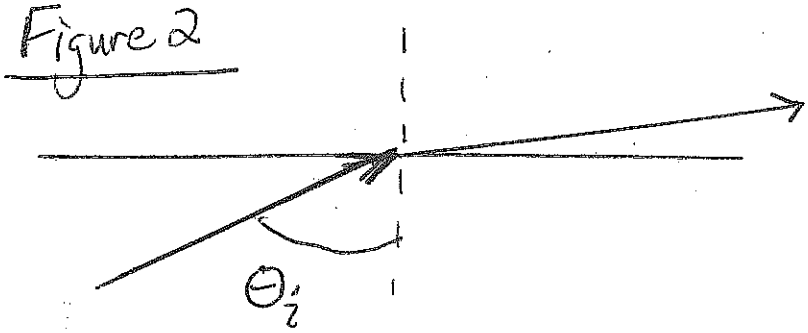
(15)

Figure 1



- When light goes from a material that transmits light slowly to a material that transmits light faster, then it bends away from the normal (i.e. toward the boundary). See figure 1.
- If the light comes in at a greater incident angle, then the refracted light will be even closer to the boundary. See figure 2.

Figure 2



- For a sufficiently large incident angle (critical angle), the refracted ray will travel straight down the boundary. See figure 3.

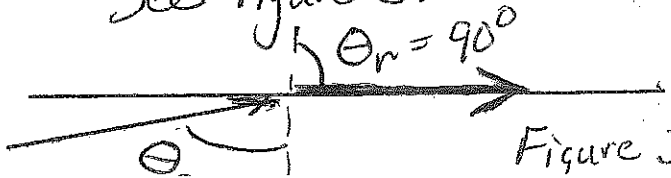


Figure 3

#15 cont.

Refl., Refr., & Critical Angle

- For an incident angle larger than the critical angle, there can be no refracted ray because it would have to have $\theta_r > 90°$ and this would not be refraction because the light wouldn't be going into the new material. For incident angles larger than the critical angle, all the incident light will be reflected back into the incident medium (100% internal reflection).

(3) If $n_i < n_r$, then the refracted ray would bend toward the normal. The refracted ray must bend toward the boundary in order to get the situation shown in figure 3 and a critical angle.