

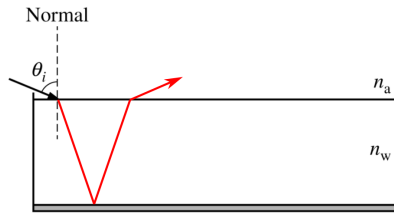
Question 1: Short Answer

10 points

- (a) For drawing a straight-line path from the entry point to the bottom of the tank with an angle from the normal that is less than θ_i **1 point**

For drawing a continuous path that is symmetric about a vertical axis that intersects the mirror at the location where the beam of light is incident upon the mirror **1 point**

Example Response

Total for part (a) **2 points**

- (b) For indicating that the wavelength of light decreases without any incorrect statements **1 point**

Example Response

As light travels from one medium to a medium that has a higher index of refraction, the speed of light decreases and the frequency of the light remains the same. Therefore, the wavelength of the light decreases, as described by the equation $\lambda = \frac{v}{f}$.

Total for part (b) **1 point**

- (c)(i) For a correct application of Snell's law for two media boundaries **1 point**

Scoring Note: If a test taker correctly applies Snell's law for air and the bottom layer, this point can be earned.

Example Response

$$\theta_4 = \sin^{-1}\left(\frac{n_a}{n_b}\sin\theta_i\right) \text{ OR } \sin\theta_4 = \frac{n_a}{n_b}\sin\theta_i$$

Example Solution

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

$$n_a \sin\theta_i = n_w \sin\theta_2 = n_m \sin\theta_3 = n_b \sin\theta_4$$

$$n_a \sin\theta_i = n_b \sin\theta_4$$

$$\sin\theta_4 = \frac{n_a}{n_b}\sin\theta_i$$

$$\theta_4 = \sin^{-1}\left(\frac{n_a}{n_b}\sin\theta_i\right)$$

- (c)(ii) For indicating that θ_4 alone is the smallest angle **1 point**

For indicating that θ_2 alone is the largest angle **1 point**

For indicating that $\theta_1 = \theta_3$ **1 point**

For an explanation that correctly relates the index of refraction to an angle **1 point**

Example Response

$$\underline{\quad 2 \quad} \theta_1 \quad \underline{\quad 1 \quad} \theta_2 \quad \underline{\quad 2 \quad} \theta_3 \quad \underline{\quad 3 \quad} \theta_4$$

θ_2 has the greatest value because water has the lowest index of refraction. θ_1 and θ_3 are equal because each is in the same layer with the same index of refraction, but the angles are smaller than θ_2 because the index of refraction is larger in this layer. θ_4 has the smallest value because the bottom layer has the highest index of refraction.

Total for part (c) **5 points**

- (d) For indicating that both d_A and d_B are less than d_w , with an attempt at a relevant explanation **1 point**

For correctly indicating that the horizontal distance traveled decreases with increasing refraction toward the normal **1 point**

Example Response

Horizontal distances d_A and d_B are less than d_w . The light rays for all scenarios are entering from air. However, in models A and B, the light rays enter a medium with an index of refraction that is greater than that of water. Therefore, the light rays bend more toward the normal in models A and B than in the original tank. Bending more toward the normal results in a shorter horizontal distance traveled.

Total for part (d) **2 points**Total for question 1 **10 points**