

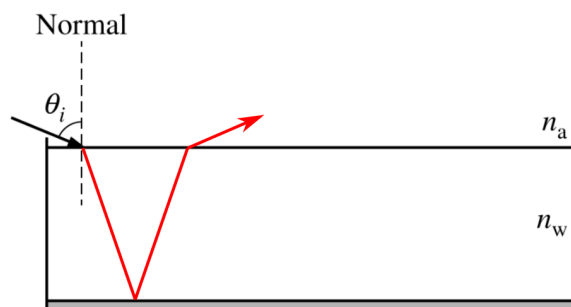
Question 1: Short Answer

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

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

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