Bending Light

Read, graph, calculate, and sketch how a light ray changes direction.

HS-PSII-8.2 "Develop graphical, mathematical, and pictorial representations (e.g., ray diagrams) that describe the relationship between the angles of incidence and refraction of monochromatic light passed between two different media and apply those..."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline where the passage says to measure angles, circle the sentence that predicts how the ray bends in water, and number the table's nonzero rows from smallest to largest incident angle.

A Laser at the Aquarium Wall

1. A single-color laser shines through the flat wall of an aquarium. Where its ray crosses from air into water, draw a line perpendicular to the wall, called the normal. Measure both angles from this line, not from the wall. The incoming angle is the angle of incidence. The angle inside water is the angle of refraction.

2. The table records angles for a ray entering water from air, rounded to the nearest degree. As the incident angle grows, the refracted angle also grows, but it stays smaller than the incident angle except at zero. In a ray sketch, the water ray therefore bends toward the normal. On a graph, put incidence on the horizontal axis and refraction on the vertical axis.

LASER LIGHT TRAVELING FROM AIR INTO WATER

Incidence in air (°)	Refraction in water (°)
0	0
30	22
45	32
60	41
75	47

3. Snell's law links the angles: $n_{air} \sin(i) = n_{water} \sin(r)$. For this light, use $n_{air} = 1.00$ and $n_{water} = 1.33$. For a ray going from water into air, swap the indices. To find its outgoing angle, calculate $\sin^{-1}(1.33 \sin(i))$ in degree mode, if the value inside $\sin^{-1}$ is at most 1.

2 ANSWER WITH EVIDENCE

Use the passage

1. A ray strikes the aquarium wall at 45° from the normal. What angle should you label inside the water, and does the ray bend toward or away from the normal?

2. If the incident angle changes from 30° to 60°, by how many degrees does the refracted angle change?

3. List the graph coordinates (incidence, refraction) for 0°, 45°, and 75° incidence. Where do the nonzero points fall relative to the line y = x?

4. Using the 30° row, estimate sin(i) ÷ sin(r) to two decimal places. How does your result compare with n_{water} ÷ n_{air}?

3 YOUR TURN

Your own words

Now send the ray from water into air. In separate panels, sketch rays with incident angles of 15° and 35° from the normal, label their refracted angles to the nearest degree using Snell's law, and write one sentence comparing the bends.

ANSWER KEY

Bending Light

PART 1 · READ AND MARK

Underline where the passage says to measure angles, circle the sentence that predicts how the ray bends in water, and number the table's nonzero rows from smallest to largest incident angle. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	A ray strikes the aquarium wall at 45° from the normal. What angle should you label inside the water, and does the ray bend toward or away from the normal?	**Label the water angle 32°. The ray bends toward the normal.**
2	If the incident angle changes from 30° to 60°, by how many degrees does the refracted angle change?	**It changes from 22° to 41°, an increase of 19°.**
3	List the graph coordinates (incidence, refraction) for 0°, 45°, and 75° incidence. Where do the nonzero points fall relative to the line y = x?	**(0, 0), (45, 32), and (75, 47). The nonzero points fall below y = x.**
4	Using the 30° row, estimate sin(i) ÷ sin(r) to two decimal places. How does your result compare with $n_{water} \div n_{air}$?	**sin(30°) ÷ sin(22°) ≈ 1.33. This matches 1.33 ÷ 1.00 = 1.33, allowing for rounded angles.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

Panel 1: A ray in water meets the surface at 15° from the normal and exits into air at 20°. Panel 2: A ray in water meets the surface at 35° from the normal and exits into air at 50°. Both rays bend away from the normal, and the ray with the larger incident angle has the larger refracted angle.

Accept angles within 1° of 20° and 50° when students use 1.33 for water's index. In each sketch, check that both angles are measured from the normal and the air ray bends away from it.