Unit 15 · Refraction at Plane Surfaces

HARDER PRACTICE QUESTIONS

Full marks 35

Write your answers on separate paper. Show your working. Take the refractive index of water as 1.33 and the speed of light in a vacuum as 3×10^8 m/s.

1 Spot the error [3]

Find the mistake in the working and correct it.

Bibek was asked: "Looking straight down into a clear pool, a stone on the bottom seems to be 1.2 m deep. How deep is the pool?" He wrote:
"Water makes things look shallower, so I divide by μ: the pool is $1.2 \div 1.33 = \mathbf{0.90\ m}$ deep."

2 A lamp under water [4]

A small lamp lies on the bottom of a still pond 2.0 m deep.

i. Explain why light from the lamp leaves the surface only through a circle.
ii. Find the radius of the circle.
iii. What happens to the radius if the water level drops to 1.0 m? And if the pond were filled with a liquid of larger refractive index?

3 Check the readings [4]

Utsab passed rays from air into a glass block at different angles of incidence and measured the angles of refraction.

i	20°	30°	40°	50°	60°
r	13.0°	19.5°	27.5°	30.5°	35.5°

i. Find sin i ÷ sin r for each reading.
ii. Which reading does not fit Snell's law? What should r have been there?
iii. Give the refractive index of the glass.
iv. How would a graph of sin i against sin r show that Snell's law holds?

4 How much light can a fiber take in? [4]

The core of an optical fiber has a refractive index of 1.50 and its cladding 1.40. Light enters the flat end of the fiber from air at an angle θ to its axis.

i. Find the critical angle at the core–cladding boundary.
ii. Find the largest angle of refraction at the end face for which the light still meets the cladding at the critical angle or more.
iii. Hence find the largest θ for which the light is trapped in the fiber.

5 Predict, then explain [3]

Write your prediction first, then explain it.

Nischal puts a clear glass rod into a beaker of a clear liquid whose refractive index is exactly the same as the glass's. Predict what he sees of the part of the rod inside the liquid, and explain.

6 Check an approximation [3]

For small angles of incidence, the lateral shift through a slab is $L \approx t\, i\, (1 - 1/\mu)$, with i in radians. For a slab 5.0 cm thick ($\mu = 1.5$) and $i = 10°$, find L by this and by the exact formula, and say by what percentage the approximation is off.

7 Estimate it [2]

A pulse of light travels 50 km along an optical fiber whose core has a refractive index of about 1.5. Estimate how long it takes, and how much longer than it would take through air over the same distance.

8 Which explanation fits the evidence? [3]

A crack inside a glass window shines brightly, but only when it is seen from certain directions. Two students explain:

Prapti: "The crack is a thin layer of air. Light inside the glass meeting it at more than the critical angle is totally reflected."

Sangam: "Dust in the crack is shiny, like metal, and reflects the light."

Which explanation fits the evidence? Explain why.

9 Design an experiment [4]

Sakshi has a rectangular glass block, a sheet of paper, pins, a protractor and a ruler. Plan how she can find the refractive index of the glass.

i. What will she draw and mark on the paper?
ii. What will she measure?
iii. How will she get μ from her measurements?
iv. How can she make her answer more reliable?

10 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

Kushal wrote: "Kerosene is lighter than water, so it is optically rarer. When light passes from air into water its frequency drops, which is why it bends. If light in air meets a glass surface at a very large angle, almost 90°, it is totally reflected."

11 Think [2]

A piece of glass cut into exactly the same shape as a diamond sparkles far less than the diamond. Why?