Unit 13 · Light

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 45

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

She has used the angle with the surface. Angles are measured from the **normal**, so i = 90° − 30° = 60°. sin r = sin 60° ÷ 1.33 = 0.866 ÷ 1.33 = 0.651, so r = **40.6**°.

MARKING SCHEME

✓ The mistake: the angle of incidence is measured from the normal, not the surface.
✓ i = 60°.
✓ r = 40.6°.

2 Inside a fiber

ANSWER A · 5

i. $v = 3 \times 10^8 \div 1.48 = 2.03 \times 10^8$ m/s. $t = 1 \times 10^5 \div 2.03 \times 10^8 =$ **4.9×10^{-4} s**. Through air: $1 \times 10^5 \div 3 \times 10^8 = 3.3 \times 10^{-4}$ s, so it takes **1.6×10^{-4} s** longer.
ii. sin c = 1.46 ÷ 1.48 = 0.986, so c = **80.6**°.
iii. 85° is more than 80.6°: **totally reflected**. 75° is less: part of it **leaks into the cladding**.
iv. sin c = 1 ÷ 1.48, so c = **42.5**°. 75° is now more than the critical angle, so the ray is held: for this ray it is **better**.

MARKING SCHEME

✓ $t = 4.9 \times 10^{-4}$ s, 1.6×10^{-4} s longer than through air.
✓ c = 80.6°.
✓ 85° totally reflected.
✓ 75° leaks into the cladding.
✓ c = 42.5° in air, so the 75° ray is held.

3 Check the readings

ANSWER HA · 4

i. i ÷ r: 1.52, 1.57, 2.00, 1.95. sin i ÷ sin r: 1.50, 1.50, 1.73, 1.50.
ii. **No.** i ÷ r keeps rising, even leaving out the odd reading (1.52, 1.57, 1.95), so the angles are not in a fixed ratio; it is their sines that are.
iii. **r = 30.0° at i = 60°**: its sine ratio is 1.73, while the others are all 1.50.
iv. sin r = sin 60° ÷ 1.50 = 0.577, so r ≈ **35.3**°.

MARKING SCHEME

✓ Both rows of the table.
✓ The claim is wrong: the ratio of the angles is not constant, the ratio of the sines is.
✓ The reading at i = 60°.
✓ r ≈ 35.3°.

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4 Show that

ANSWER A · 4

i. $\sin r = 0.766 \div 1.33 = 0.576$, so r = **35.2**°.

ii. The ray meets the glass at 35.2°, so $1.5 \sin r = 1.33 \times 0.576 = 0.766$; $\sin r = 0.511$, so r = **30.7**°.

iii. Directly from air: $\sin r = 0.766 \div 1.5 = 0.511$, so r = **30.7**°, the same.

iv. Along the ray, $\mu \sin$ (angle) stays the same at each flat surface: $1 \times \sin 50° = 1.33 \times \sin r_w = 1.5 \times \sin r_g$. The water's term comes in and goes out, so only the first and last media matter.

MARKING SCHEME

- ✓ 35.2° in the water.
- ✓ 30.7° in the glass.
- ✓ 30.7° with no water, the same.
- ✓ $\mu \sin \theta$ is the same at every parallel surface, so the water cancels.

5 A wet prism

ANSWER HA · 4

The view goes dim or disappears, because the light leaks out.

With air outside, the critical angle is 41.8°; 45° is more, so the light is totally reflected.

With water outside: $\sin c = 1.33 \div 1.5 = 0.887$, so c = **62.5**°. Now 45° is **less** than the critical angle, so most of the light gets out into the water: $\sin r = 1.5 \times \sin 45° \div 1.33 = 0.797$, so r = **52.9**°.

MARKING SCHEME

- ✓ The view dims or disappears.
- ✓ The critical angle becomes 62.5°.
- ✓ 45° is less than it, so total internal reflection stops.
- ✓ r = 52.9° in the water.

6 Work backwards

ANSWER A · 3

Apparent depths add up. The water looks $16 \div (4/3) = 12$ cm deep, so the kerosene looks $17 - 12 = 5$ cm deep.

Thickness $= 5 \times 1.44 =$ **7.2 cm**. Real depth $= 16 + 7.2 =$ **23.2 cm**. Raised by $23.2 - 17 =$ **6.2 cm**.

MARKING SCHEME

- ✓ The water looks 12 cm deep, so the kerosene 5 cm.
- ✓ Kerosene 7.2 cm thick; real depth 23.2 cm.
- ✓ Raised by 6.2 cm.

7 The missing reading

ANSWER A · 3

The apparent shift is $3.50 - 2.00 = 1.50$ cm. Shift $= t \times (1 - 1/\mu) = t \times (1 - 1/1.5) = t \div 3$, so t = **4.50 cm**.

Top reading $= 2.00 + 4.50 =$ **6.50 cm**.

(Check: real $4.50 \div$ apparent $(6.50 - 3.50 = 3.00) = 1.5$.)

MARKING SCHEME

- ✓ Shift = 1.50 cm.
- ✓ Shift = t ÷ 3, so t = 4.50 cm.
- ✓ Top reading 6.50 cm.

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8 The floating disc

ANSWER HA · 3

Light from the coin leaves only through the circle where its angle of incidence is less than 48.8°. The disc just hides the coin when the disc's radius equals that circle's radius, R = d tan c: 0.57 = d × 1.14, so d = **0.50 m**.

In a deeper pond the circle is **wider than the disc**, so light gets out round its edge, and the coin **can** be seen.

MARKING SCHEME

- ✓ R = d tan c, the disc just covering the circle of light.
- ✓ d = 0.50 m.
- ✓ Deeper: the circle is wider than the disc, so the coin can be seen.

9 Design a fair test

ANSWER A · 4

i. She changes the amount of sugar in the same volume of water (none, then more each time), and uses the microscope's three readings to find μ = real depth ÷ apparent depth.

ii. Any three: the same beaker; the same depth of liquid; looking straight down; the same color of light; stirring until dissolved; the same person focusing.

iii. Repeat each focus several times and average; use a deep liquid so that the shift is large.

iv. μ rises steadily as more sugar is dissolved, above about 1.33 for plain water.

MARKING SCHEME

- ✓ Changes the amount of sugar; measures real and apparent depth to find μ.
- ✓ Any three things kept the same.
- ✓ Repeats and averages.
- ✓ μ rises with more sugar.

10 Correct the misconceptions

ANSWER U · 3

1. Optically denser is about the speed of light, not mass. Light is slower in kerosene (μ about 1.44) than in water (1.33), so kerosene is optically **denser**.
2. Along the normal, light **doesn't bend**, although its speed changes.
3. At a slant, a pool looks **shallower still**.

MARKING SCHEME

- ✓ Kerosene is optically denser than water.
- ✓ Along the normal there is no bending.
- ✓ At a slant it looks shallower, not deeper.

11 Which explanation fits the evidence?

ANSWER HA · 3

Sapana. Both theories gave the same law of sines, so the law can't choose between them. Newton's particles should go **faster** in water, and Huygens's waves **slower**. In 1850 Foucault measured light as slower in water than in air, which supports the wave theory.

MARKING SCHEME

- ✓ Sapana is right; both theories gave the law of sines, so it can't decide.
- ✓ Newton: faster in water. Huygens: slower in water.
- ✓ Foucault measured it slower in water, supporting waves.

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12 Make your own

ANSWER HA · 2

For example: glass into water, sin c = 1.33 ÷ 1.5, c = 62.5°; 70° is more, so it is **totally reflected**. Water into ice, sin c = 1.31 ÷ 1.33, c = 80.1°; 70° is less, so it is **not**. (Others: diamond into glass, c = 38.3°, reflected.)

MARKING SCHEME

- ✓ A pair going denser to rarer with a critical angle under 70°, worked out.
- ✓ A pair where the critical angle is over 70°, or going rarer to denser.

13 Think

ANSWER HA · 4

i. $1 \div (4/3) =$ **0.75 m**.
ii. $3 + 0.75 =$ **3.75 m**.
iii. $3 \times 4/3 =$ **4 m** above the surface.
iv. $4 + 1 =$ **5 m**. Each sees the other's image, not the other: the bird sees the fish raised, and the fish sees the bird raised too. So the two image distances differ, though the real distance is 4 m both ways; $5 = 3.75 \times 4/3$.

MARKING SCHEME

- ✓ 0.75 m below the surface.
- ✓ 3.75 m from the bird.
- ✓ 4 m above the surface.
- ✓ 5 m from the fish; each sees an image, raised, not the real position.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Rays of Light** (exhibit): Slant the block in a beam and check the angle scale: the beam bends toward the normal going in, and away from it coming out.
- **The Water Bowl Magnifier** (exhibit): Look at the pebbles through the curved bowl of water: light bends at each surface, and the pebbles look bigger or out of shape.
- **Total Internal Reflection** (exhibit): Inside each fiber, light meets the wall at more than the critical angle and is totally reflected, so it escapes only at the tip.
- **The Ecosystem Pond** (exhibit): Look down at the pebbles on the pond's bottom: they seem nearer the surface than they really are. That is apparent depth.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	19	20	**45**

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