3.2 Light refraction and sound

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

Objective

Build the skills to answer exam questions on **light and sound** : reflection and refraction, refractive index, critical angle and total internal reflection, optical fibres, sound waves, echoes, hearing and oscilloscope traces.

You must be able to:

- use the law of reflection and $n = \sin i \div \sin r$
- calculate a critical angle and explain total internal reflection
- calculate distances from echoes and frequencies from oscilloscope traces
- plan an experiment to measure refraction in a glass block

1 Key knowledge and worked examples

Light and sound

idea	equation or rule
reflection	angle of incidence = angle of reflection (both measured from the normal)
refraction	light slows down and bends towards the normal when it enters a denser material
refractive index	$n = \sin i \div \sin r$
critical angle	$\sin c = 1 \div n$; above c, total internal reflection happens inside the denser material
sound	a longitudinal wave; needs a medium; humans hear about 20–20 000 Hz
distance and speed	distance = speed × time

Worked example 1: refractive index. A ray enters a block with $i = 45°$ and $r = 28°$. Find n.

1. Known: $i = 45°$; $r = 28°$.
2. Rule: $n = \sin i \div \sin r$.

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3. Numbers: $0.707 \div 0.469$.
4. Result: $n = 1.51$.

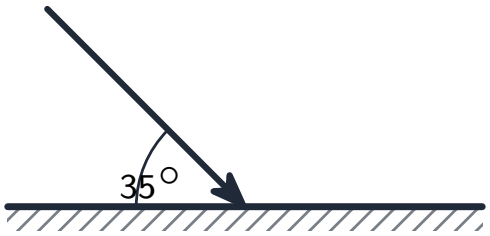
Worked example 2: critical angle. Water has $n = 1.33$. Find its critical angle.

1. Known: $n = 1.33$.
2. Rule: $\sin c = 1 \div n$.
3. Numbers: $\sin c = 0.752$.
4. Result: $c = 49°$.

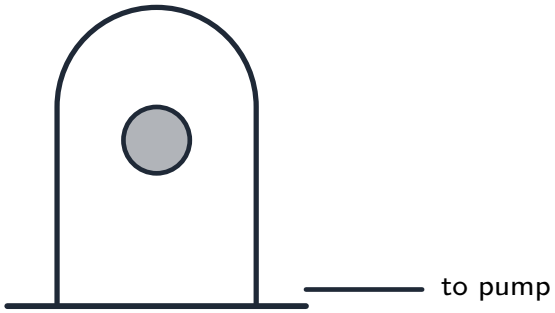
Answer shapes: measure every angle from the normal, not from the surface.

2 Practice

2.1 A ray of light hits a plane mirror at 35° to the mirror surface. Find the angle of reflection. [2]

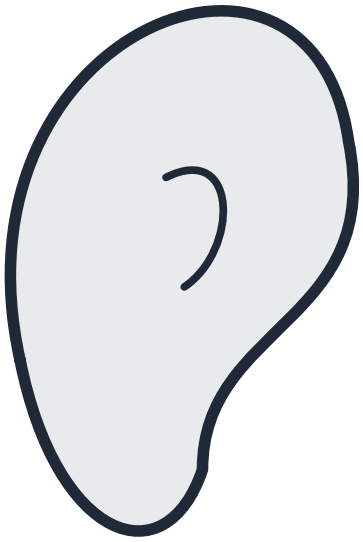


2.2 Explain why sound cannot travel through space, but light can. [2]

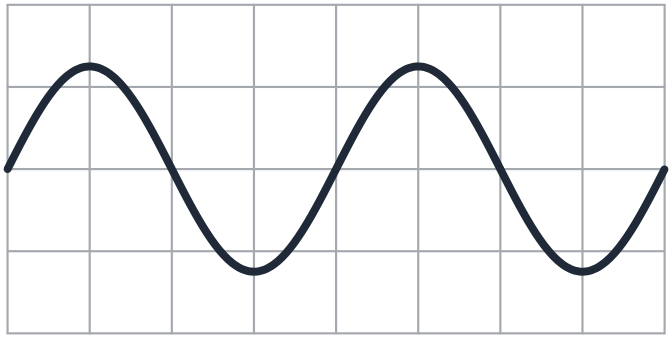


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2.3 State the range of human hearing, and explain what ultrasound is. [2]



2.4 One complete wave on an oscilloscope covers 4 squares. Each square is 0.5 ms. Calculate the frequency. [2]



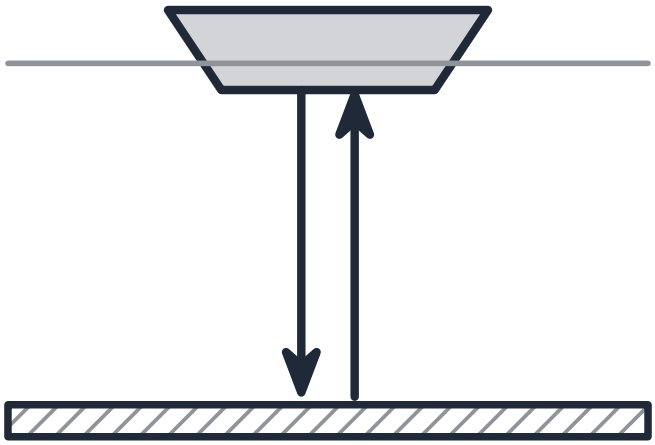
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3 Exam-style questions

3.1 Explain how light travels along an optical fibre. [3]

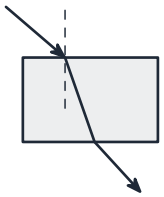


3.2 A ship sends a sound pulse to the sea bed and hears the echo 0.50 s later. Sound travels at 1500 m/s in sea water. Calculate the depth of the sea. [3]



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3.3 A student shines a ray of light into a glass block at different angles of incidence and measures the angle of refraction. The results are shown.



i / °	20	30	40	50	60
r / °	13	19	25	30	35

(a) Use the results for $i = 40°$ to calculate the refractive index of the glass. [3]

(b) Calculate the critical angle of the glass, and explain what happens to a ray inside the block that hits the surface at 50°. [4]

(c) Use your refractive index to predict the angle of refraction when $i = 60°$, and compare it with the result. [3]

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(d) Describe how the student should measure the angles of incidence and refraction. [6]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

- angle of incidence $= 90 - 35 = 55°$
- angle of reflection $=$ **55**°

2.2

- sound needs particles (a medium) to vibrate, and space is a vacuum
- light is an electromagnetic wave, which does not need a medium

2.3

- 20 Hz to 20 000 Hz
- ultrasound is sound above 20 000 Hz, too high for humans to hear

2.4

- $T = 4 \times 0.5 = 2.0$ ms $= 0.0020$ s
- $f = 1 \div 0.0020 =$ **500** Hz

3.1

- light hits the inside surface of the glass at an angle greater than the critical angle
- it is totally internally reflected
- this happens again and again, so the light stays in the fibre even round bends

3.2

- distance travelled $= 1500 \times 0.50 = 750$ m
- this is there and back
- depth $=$ **375** m

3.3

(a) $\sin 40 = 0.643$; $\sin 25 = 0.423$; $n = 0.643 \div 0.423 =$ **1.52**

(b) $\sin c = 1 \div 1.52 = 0.658$; $c =$ **41**°; 50° is greater than the critical angle; so the ray is totally internally reflected

(c) $\sin r = \sin 60 \div 1.52 = 0.866 \div 1.52 = 0.570$; $r = 35°$; this agrees with the measured 35°

(d) points to include:

- place the block on paper and draw round it (K)
- shine a narrow ray from a ray box at the block; mark the ray going in and coming out with crosses (K)
- remove the block, join the points and draw the ray through the block (K)
- draw the normal at the point where the ray enters, at 90° to the surface (K)

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- measure i and r from the normal with a protractor (K)
- repeat for several angles of incidence; use a thin ray and a dark room for accuracy (App)

Levels: **5–6** a full, logical answer with correct physics and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.

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