3.2 Sound reflection refraction and lenses

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

KEY WORDS refractive index • total internal reflection

Objective

Build the skills to answer exam questions on **sound, ultrasound, reflection, refraction and lenses** 、 、 、 : hearing range, pitch and loudness, echoes, the law of reflection, refractive index, total internal reflection and images formed by lenses.

You must be able to:

- describe sound waves, pitch and loudness, and the range of human hearing
- use echoes and $s = vt$ to find distances with ultrasound
- use the law of reflection and $n = \frac{\sin i}{\sin r}$
- explain total internal reflection and describe images formed by a converging lens

1 Key knowledge and worked examples

Sound and light

idea	equation or rule
sound	longitudinal, needs a medium; humans hear 20 Hz to 20 000 Hz; higher frequency is higher pitch, larger amplitude is louder
ultrasound echo	above 20 000 Hz; distance $= \frac{vt}{2}$ (there and back)
reflection, refraction	angle of incidence = angle of reflection, from the normal; light slows in glass and bends towards the normal; $n = \frac{\sin i}{\sin r}$
total internal reflection	inside glass, at more than the critical angle c; $\sin c = \frac{1}{n}$; used in optical fibres
converging lens	parallel rays meet at the principal focus F; a real image can go on a screen; a magnifying glass gives a virtual, upright, larger image

Worked example 1: an echo. An ultrasound pulse travels at 1500 m/s in the body. Its echo returns after 0.00020 s. How deep is the boundary?

1. Known: $v = 1500$ m/s, $t = 0.00020$ s for there and back.
2. Rule: distance $= \frac{vt}{2}$.
3. Numbers: $\frac{1500 \times 0.00020}{2}$.
4. Result: 0.15 **m**.

Worked example 2: refractive index. Light enters glass with angle of incidence 40° and angle of refraction 25°. Find the refractive index.

1. Known: $i = 40°$, $r = 25°$.
2. Rule: $n = \frac{\sin i}{\sin r}$.
3. Numbers: $\frac{0.643}{0.423}$.
4. Result: $n = 1.52$.

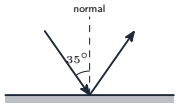
Answer shapes: measure angles from the normal, not from the surface; for an echo, halve the distance.

2 Practice

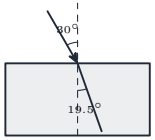
2.1 Which of these sounds can a human hear? Which one is ultrasound? [2]

15 Hz | 200 Hz | 18 000 Hz | 30 000 Hz

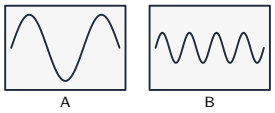
2.2 A ray of light hits a mirror. The angle of incidence is 35°. Write down the angle of reflection and the angle between the reflected ray and the mirror. [2]



2.3 Light enters a glass block with angle of incidence 30°. The angle of refraction is 19.5°. Calculate the refractive index of the glass. [2]

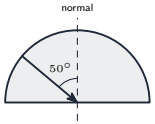


2.4 The diagram shows two sound waves on an oscilloscope. The settings are the same. Which sound is louder? Which has the higher pitch? [2]

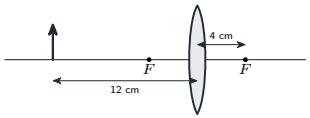


3 Exam-style questions

3.1 A glass has refractive index 1.50. Calculate its critical angle. What happens to light inside the glass that hits the surface at 50°? [3]

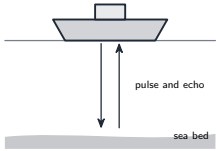


3.2 An object stands 12 cm from a converging lens. The lens has a focal length of 4 cm. Describe the image formed. [3]



3.3 A ship uses pulses of ultrasound to measure the depth of the sea. The speed of sound in sea water is 1500 m/s.

(a) A pulse returns after 0.080 s. Calculate the depth of the sea. [3]



(b) The ultrasound has a frequency of 40 kHz. Calculate its wavelength in water. Explain why it is called ultrasound. [4]

(c) Over a group of fish, an echo returns after 0.030 s. Calculate the depth of the fish. Explain why the ship also receives a second echo. [3]

(d) Describe how ultrasound is used to make an image of an unborn baby. Explain why ultrasound is used and not X-rays. [6]

Solutions

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

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

2.1

- humans hear 200 Hz and 18 000 Hz; 30 000 Hz is ultrasound

2.2

- angle of reflection = **35**°; angle with the mirror = $90° - 35° = \mathbf{55}°$

2.3

- $n = \frac{\sin 30°}{\sin 19.5°}$; $= \mathbf{1.5}$

2.4

- **A** is louder: larger amplitude; **B** has the higher pitch: higher frequency

3.1

- $\sin c = \frac{1}{1.50}$
- $c = \mathbf{41.8}°$
- 50° is more than c, so **total internal reflection**

3.2

- **real**
- **inverted** (upside down)
- **smaller** than the object (diminished)

3.3

(a) $s = vt = 1500 \times 0.080 = 120$ m; there and back, so ÷2; depth = **60** m

(b) $\lambda = \frac{v}{f}$; 40 kHz = 40 000 Hz; $\lambda = \mathbf{0.0375}$ m; its frequency is above 20 000 Hz, too high for humans to hear

(c) $\frac{1500 \times 0.030}{2} = \mathbf{22.5}$ m; the first echo is from the fish; the rest of the pulse goes on and reflects from the sea bed

(d) points to include:

- a probe sends ultrasound pulses into the body; part reflects at each tissue boundary
- the probe detects the echoes and the time for each is measured
- distance = $\frac{vt}{2}$; a computer builds an image from the echoes
- ultrasound is not ionising, so it does not damage the baby's cells
- X-rays are ionising and could harm the growing baby

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.