A-LEVEL PHYSICS • EXERCISE SHEET

24.1 Production and use of ultrasound

Name: ______________ Class: __________ Date: ____________ **Total: 25 marks**

KEY WORDS ultrasound 超声波 • specific acoustic impedance 声阻抗 • transducer 换能器 • intensity reflection coefficient 强度反射系数 • piezo-electric 压电

Objective

Build the skills to answer exam questions on **ultrasound** in medicine.

You must be able to:

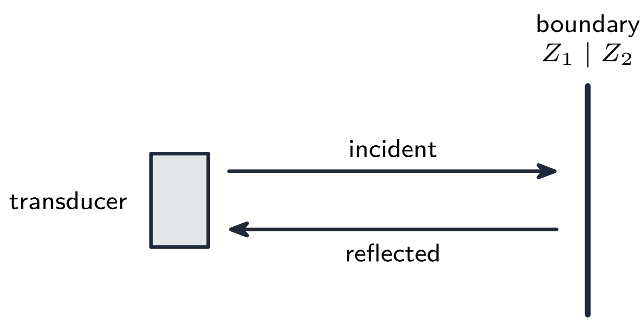
- explain the **piezo-electric** transducer (send and detect)
- use **acoustic impedance** $Z = \rho c$ and the **reflection coefficient**
- use the attenuation $I = I_0 e^{-\mu x}$

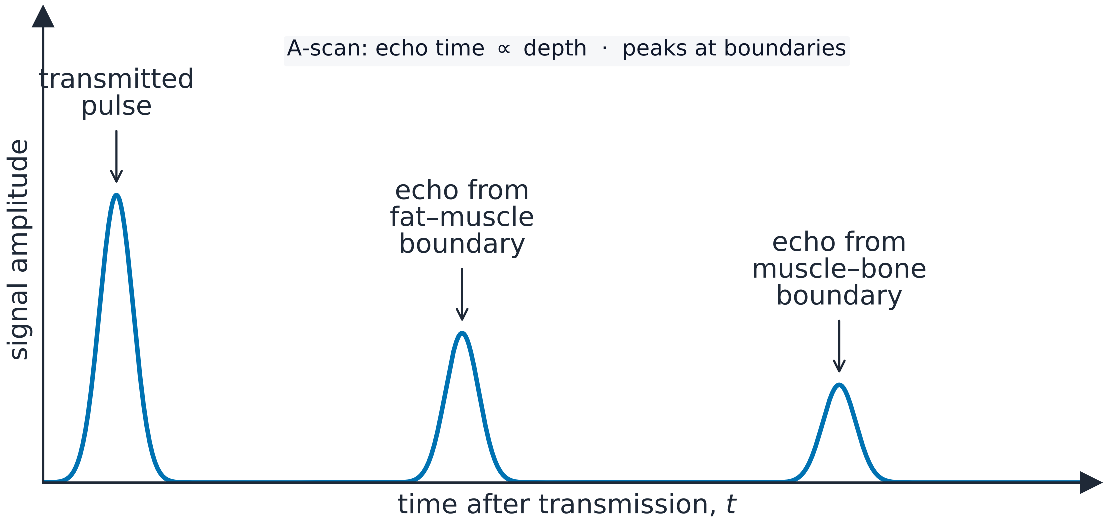
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Transducer and pulse-echo

A **piezo-electric** crystal changes shape when a p.d. is applied (to **emit** ultrasound) and produces an e.m.f. when squeezed (to **detect** it) — so one transducer both sends and receives. A pulse partly **reflects** at a boundary between tissues:





An ultrasound A-scan trace

$$Z = \rho c, \qquad \frac{I_R}{I_0} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}, \qquad I = I_0 e^{-\mu x}.$$

A large impedance **mismatch** reflects strongly — which is why a **coupling gel** removes the air gap (air's Z is very different).

2 Practice

Now apply the methods above.

2.1 Describe the **piezo-electric effect**. [2]

2.2 Define the **specific acoustic impedance** of a medium. [1]

2.3 Explain how **one** transducer can both send and detect ultrasound. [2]

2.4 Write the equation for the **attenuation** of ultrasound. [1]

3 Exam-style questions

3.1 For a **strong** reflection at a tissue boundary, the two acoustic impedances must be: [1]

A	B
C	D

A equal
B very different
C both zero
D both very large

3.2 Calculate the intensity reflection coefficient for a boundary where $Z_1 = 1.6 \times 10^6$ and $Z_2 = 1.7 \times 10^6$ (SI units). [3]

3.3 Explain why a **coupling gel** is used between the transducer and the skin. [2]

3.4 Ultrasound of intensity I_0 passes through 5.0 cm of tissue with $\mu = 23\ \mathrm{m}^{-1}$. Calculate I/I_0. [2]

3.5 An ultrasound scanner sends a pulse into a patient. The specific acoustic impedance of soft tissue is 1.63×10^6 kg m^{-2} s^{-1}, of bone 6.40×10^6 kg m^{-2} s^{-1} and of air 4.29×10^2 kg m^{-2} s^{-1}.

(a) **Define specific acoustic impedance**. [1]

(b) **Explain** how a piezoelectric crystal **detects** the reflected ultrasound. [2]

(c) **Determine** the intensity reflection coefficient at a soft tissue-bone boundary. [3]

(d) **Determine** the intensity reflection coefficient at a soft tissue-air boundary, and **explain** why a gel is smeared on the skin before a scan. [3]

(e) The pulse returns from a boundary 9.6 cm deep after 1.2×10^{-4} s. **Determine** the speed of ultrasound in the tissue. [2]