# Ultrasound

## Question paper 1

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|---|---|
| **Level** | International A Level |
| **Subject** | Physics |
| **Exam Board** | CIE |
| **Topic** | Waves |
| **Sub Topic** | Ultrasound |
| **Paper Type** | Theory |
| **Booklet** | Question paper 1 |

**Time Allowed:** **53 minutes**

**Score:** **/44**

**Percentage:** **/100**

| A* | A | B | C | D | E | U |
|---|---|---|---|---|---|---|
| >85% | '77.5% | 70% | 62.5% | 57.5% | 45% | <45% |

**1 (a)** State what is meant by the *specific acoustic impedance* of a medium.

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.....[2]

**(b)** The specific acoustic impedances $Z$ of some media are given in Fig. 10.1.

| | $Z$ / kg m$^{-2}$ s$^{-1}$ |
|---|---|
| air | $4.3 \times 10^{2}$ |
| gel | $1.5 \times 10^{6}$ |
| soft tissue | $1.6 \times 10^{6}$ |
| bone | $7.0 \times 10^{6}$ |

**Fig. 10.1**

**(i)** The density of a sample of bone is $1.7 \times 10^{3}$ kg m$^{-3}$.

Determine the wavelength, in mm, of ultrasound of frequency $9.0 \times 10^{5}$ Hz in the bone.

wavelength = ..... mm [3]

**(ii)** Ultrasound of intensity $I$ is incident normally on the boundary between two media of specific acoustic impedances $Z_1$ and $Z_2$, as shown in Fig. 10.2.

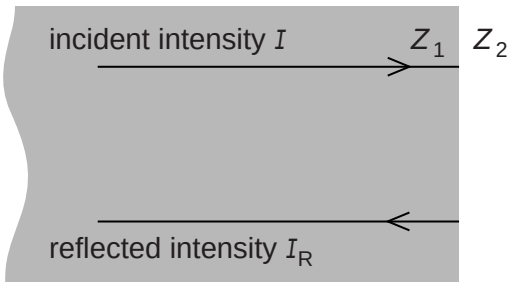


**Fig. 10.2**

The intensity of the ultrasound reflected from the boundary is $I_R$.

The ratio $\frac{I_R}{I}$ is given by the expression

$$\frac{I_R}{I} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}.$$

By making reference to the data for air, gel and soft tissue, explain quantitatively why, during medical diagnosis using ultrasound, a gel is usually put on the skin.

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**2** **(a)** By reference to ultrasound waves, state what is meant by the *specific acoustic impedance* of a medium.

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**(b)** A parallel beam of ultrasound of intensity $I$ is incident normally on a muscle of thickness 3.4 cm, as shown in Fig. 11.1.

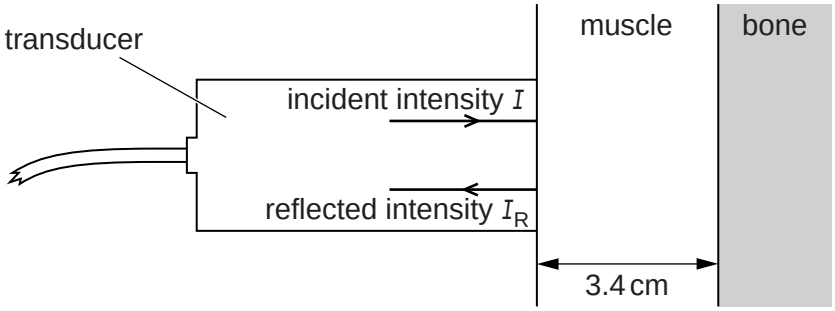


**Fig. 11.1**

The ultrasound wave is reflected at a muscle-bone boundary. The intensity of the ultrasound received back at the transducer is $I_R$.

Some data for bone and muscle are given in Fig. 11.2.

| | specific acoustic impedance / kg m$^{-2}$ s$^{-1}$ | linear absorption coefficient / m$^{-1}$ |
|---|---|---|
| bone | $6.4 \times 10^6$ | 130 |
| muscle | $1.7 \times 10^6$ | 23 |

**Fig. 11.2**

**(i)** The intensity reflection coefficient $\alpha$ for two media having specific acoustic impedances $Z_1$ and $Z_2$ is given by

$$\alpha \quad \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}.$$

Calculate the fraction of the ultrasound intensity that is reflected at the muscle-bone boundary.

fraction = ..... [2]

**(ii)** Calculate the fraction of the ultrasound intensity that is transmitted through a thickness of 3.4 cm of muscle.

fraction = ..... [3]

**(iii)** Use your answers in **(i)** and **(ii)** to determine the ratio $\frac{I_R}{I}$.

ratio = ..... [2]

**3** **(a)** Explain the main principles behind the **use** of ultrasound to obtain diagnostic information about internal body structures.

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**(b)** State and explain one advantage of the use of high frequency ultrasound as compared with low frequency ultrasound for medical diagnosis.

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**(c)** The absorption (attenuation) coefficient for ultrasound in muscle is $23\,m^{-1}$.
A parallel beam of ultrasound is passed through a muscle of thickness 6.4 cm.

**(i)** Calculate the ratio

$$\frac{\text{intensity of transmitted beam}}{\text{intensity of incident beam}}.$$

ratio = ..... [3]

**(ii)** An ultrasound transmitter emits a pulse.
Suggest why, when the signal from the pulse is processed, any signal received later at the detector is usually amplified more than that received at an earlier time.

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**4** **(a)** By reference to ultrasound waves, state what is meant by *acoustic impedance*.

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**(b)** An ultrasound wave is incident on the boundary between two media. The acoustic impedances of the two media are $Z_1$ and $Z_2$, as illustrated in Fig. 10.1.

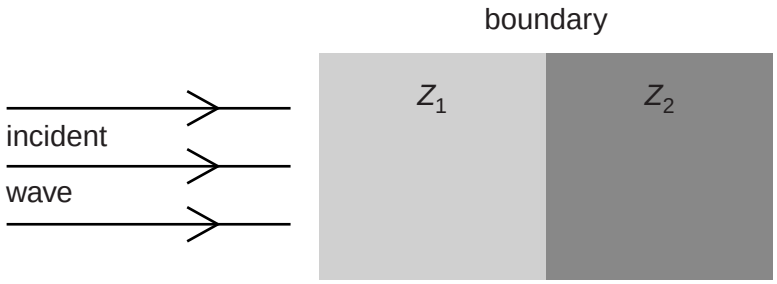


**Fig. 10.1**

Explain the importance of the difference between $Z_1$ and $Z_2$ for the transmission of ultrasound across the boundary.

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..... [3]

**(c)** Ultrasound frequencies as high as 10 MHz are used in medical diagnosis.
State and explain one advantage of the use of high-frequency ultrasound compared with lower-frequency ultrasound.

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**5** Explain the principles of the generation and detection of ultrasound waves.

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