Ultrasound

Question paper 2

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Waves
Sub Topic	Ultrasound
Paper Type	Theory
Booklet	Question paper 2

Time Allowed: **51 minutes**

Score: **/42**

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 *acoustic impedance Z* of a medium.

.....

.....[1]

(b) Two media have acoustic impedances Z_1 and Z_2.
The intensity reflection coefficient α for the boundary between the two media is given by

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

Describe the effect on the transmission of ultrasound through a boundary where there is a large difference between the acoustic impedances of the two media.

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.....[3]

(c) Data for the acoustic impedance Z and the absorption coefficient μ for fat and for muscle are shown in Fig. 10.1.

	Z / kg m^{-2} s^{-1}	μ / m^{-1}
fat	1.3×10^6	48
muscle	1.7×10^6	23

Fig. 10.1

The thickness x of the layer of fat on an animal, as illustrated in Fig. 10.2, is to be investigated using ultrasound.

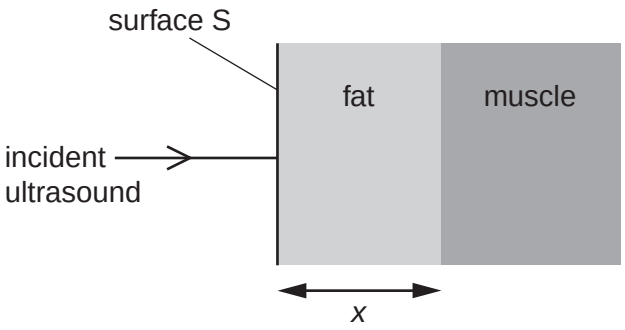

Fig. 10.2

The intensity of the parallel ultrasound beam entering the surface S of the layer of fat is I.
The beam is reflected from the boundary between fat and muscle.
The intensity of the reflected ultrasound detected at the surface S of the fat is 0.012 I.
Calculate

(i) the intensity reflection coefficient at the boundary between the fat and the muscle,

coefficient = ...[2]

(ii) the thickness x of the layer of fat.

x = ... cm [3]

2 (a) (i) State what is meant by the *acoustic impedance* of a medium.

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..... [1]

(ii) Data for some media are given in Fig. 10.1.

medium	speed of ultrasound / $m\,s^{-1}$	acoustic impedance / $kg\,m^{-2}\,s^{-1}$
air	330	4.3×10^2
gel	1500	1.5×10^6
soft tissue	1600	1.6×10^6
bone	4100	7.0×10^6

Fig. 10.1

Use data from Fig. 10.1 to calculate a value for the density of bone.

density = ... $kg\,m^{-3}$ [1]

(b) A parallel beam of ultrasound has intensity I. It is incident at right-angles to a boundary between two media, as shown in Fig. 10.2.

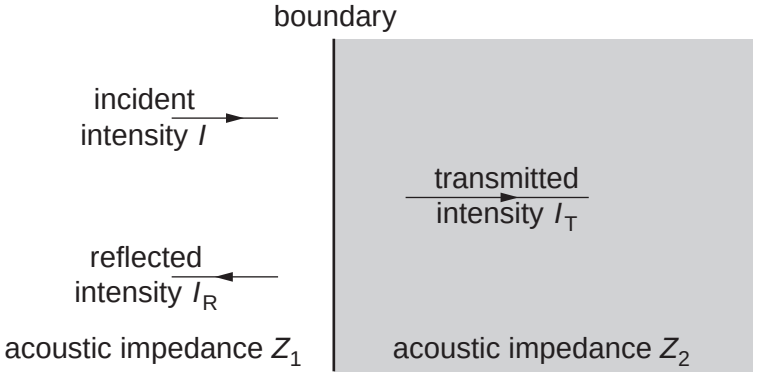

Fig. 10.2

The media have acoustic impedances of Z_1 and Z_2. The transmitted intensity of the ultrasound beam is I_T and the reflected intensity is I_R.

(i) State the relation between I, I_T and I_R.

..... [1]

(ii) The reflection coefficient α is given by the expression

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

Use data from Fig. 10.1 to determine the reflection coefficient α for a boundary between

1. gel and soft tissue,

α = ...[2]

2. air and soft tissue.

α = ...[1]

(c) By reference to your answers in **(b)(ii)**, explain the use of a gel on the surface of skin during ultrasound diagnosis.

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3 Explain the main principles behind the **generation** of ultrasound to obtain diagnostic information about internal body structures.

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

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(b) Data for the acoustic impedances and absorption (attenuation) coefficients of muscle and bone are given in Fig. 11.1.

	acoustic impedance / $kg\,m^{-2}\,s^{-1}$	absorption coefficient / m^{-1}
muscle	1.7×10^6	23
bone	6.3×10^6	130

Fig. 11.1

The intensity reflection coefficient is given by the expression

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

The attenuation of ultrasound in muscle follows a similar relation to the attenuation of X-rays in matter.

A parallel beam of ultrasound of intensity I enters the surface of a layer of muscle of thickness 4.1 cm as shown in Fig. 11.2.

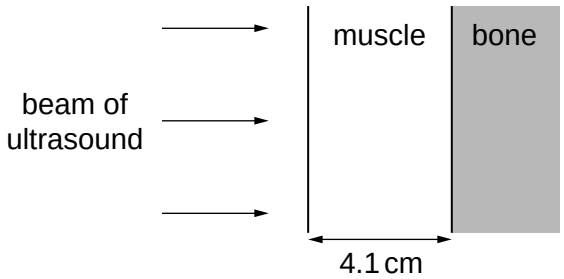

Fig. 11.2

The ultrasound is reflected at a muscle-bone boundary and returns to the surface of the muscle.

Calculate

(i) the intensity reflection coefficient at the muscle-bone boundary,

coefficient = ... [2]

(ii) the fraction of the incident intensity that is transmitted from the surface of the muscle to the surface of the bone,

fraction = ... [2]

(iii) the intensity, in terms of I, that is received back at the surface of the muscle.

intensity = ... I [2]

5 **(a)** State what is meant by *acoustic impedance*.

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(b) Explain why acoustic impedance is important when considering reflection of ultrasound at the boundary between two media.

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(c) Explain the principles behind the use of ultrasound to obtain diagnostic information about structures within the body.

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