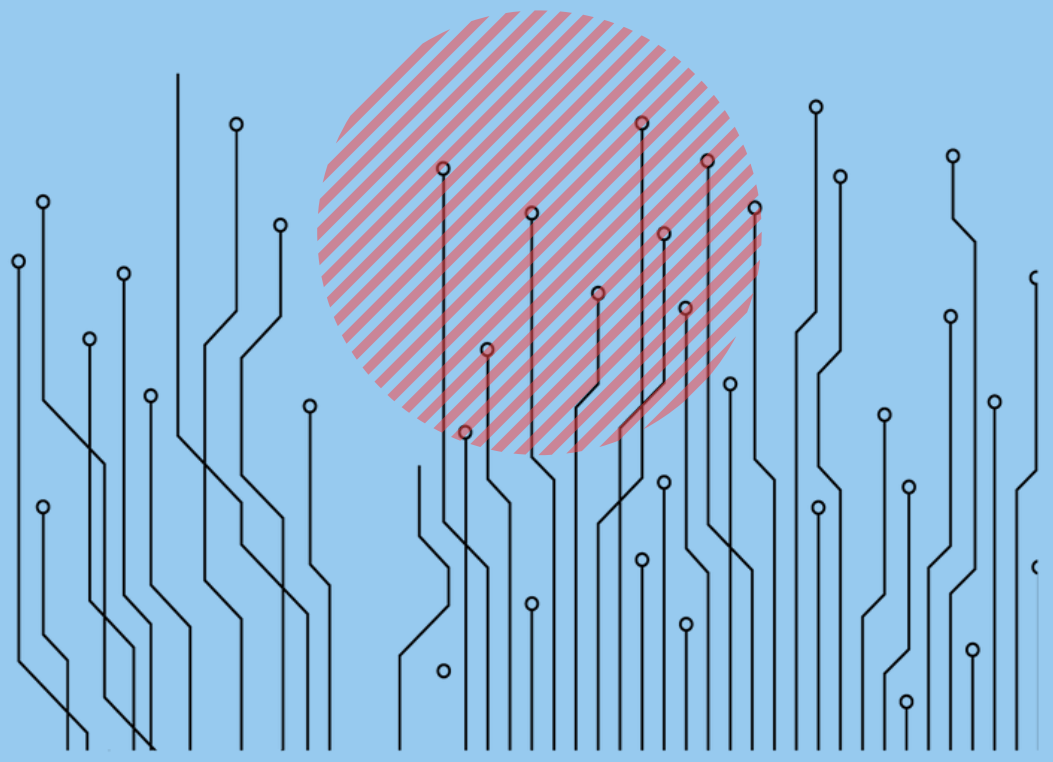
Cambridge International AS & A Level

PHYSICS

Paper 4

Topical Past Paper Questions
+ Answer Scheme

2016 - 2021



PapaCambridge

Chapter 6

Waves

118. 9702_s21_qp_41 Q: 4

Outline the **use** of ultrasound to obtain diagnostic information about internal body structures.

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119. 9702_s21_qp_43 Q: 4

Outline the **use** of ultrasound to obtain diagnostic information about internal body structures.

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120. 9702_w21_qp_42 Q: 11

(a) A piezoelectric transducer containing a quartz crystal is used to obtain diagnostic information about internal structures.

Describe the function of the quartz crystal.

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(b) **(i)** Define *specific acoustic impedance*.

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(ii) Describe, qualitatively, how the specific acoustic impedances of two materials affect the intensity reflection coefficient at a boundary between the materials.

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[Total: 7]

121. 9702_m20_qp_42 Q: 4

(a) **(i)** Explain why ultrasound used in medical diagnosis is emitted in pulses.

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(ii) Explain the principles of the **detection** of ultrasound waves used in medical diagnosis.

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(b) The specific acoustic impedances Z of some media are given in Table 4.1.

Table 4.1

media	Z / kg m^{-2} s^{-1}
air	4.3×10^2
gel	1.5×10^6
soft tissue	1.6×10^6

(i) The specific acoustic impedances of two media are Z_1 and Z_2. The intensity reflection coefficient α for the boundary of these two media is given by:

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

Calculate, to three significant figures, the fraction of the ultrasound intensity that is reflected at a boundary between air and soft tissue.

α = ... [1]

(ii) Use your value in **(b)(i)** to explain why gel is applied to the surface of the skin during an ultrasound scan.

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[Total: 8]

122. 9702_s20_qp_41 Q: 4

(a) (i) By reference to an ultrasound wave, explain what is meant by *specific acoustic impedance*.

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(ii) An ultrasound wave is incident normally on the boundary between two media. The media have specific acoustic impedances Z_1 and Z_2.

State how the ratio

$$\frac{\text{intensity of ultrasound reflected from boundary}}{\text{intensity of ultrasound incident on boundary}}$$

depends on the relative magnitudes of Z_1 and Z_2.

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(b) (i) State what is meant by the *attenuation* of an ultrasound wave.

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..... [1]

(ii) A parallel beam of ultrasound is passing through a medium.
The incident intensity I_0 is reduced to $0.35\,I_0$ on passing through a thickness of 0.046 m of the medium.

Calculate the linear attenuation coefficient μ of the ultrasound beam in the medium.

μ = ... m^{-1} [2]

[Total: 7]

123. 9702_s20_qp_42 Q: 5

(a) Explain the principles of the **detection** of ultrasound waves for medical diagnosis.

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(b) By reference to specific acoustic impedance, explain why there is very little transmission of ultrasound waves from air into skin.

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[Total: 7]

124. 9702_s20_qp_43 Q: 4

(a) (i) By reference to an ultrasound wave, explain what is meant by *specific acoustic impedance*.

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..... [2]

(ii) An ultrasound wave is incident normally on the boundary between two media. The media have specific acoustic impedances Z_1 and Z_2.

State how the ratio

$$\frac{\text{intensity of ultrasound reflected from boundary}}{\text{intensity of ultrasound incident on boundary}}$$

depends on the relative magnitudes of Z_1 and Z_2.

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..... [2]

(b) (i) State what is meant by the *attenuation* of an ultrasound wave.

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(ii) A parallel beam of ultrasound is passing through a medium.
The incident intensity I_0 is reduced to $0.35\,I_0$ on passing through a thickness of 0.046 m of the medium.

Calculate the linear attenuation coefficient μ of the ultrasound beam in the medium.

μ = ... m^{-1} [2]

[Total: 7]

125. 9702_s19_qp_42 Q: 4

(a) 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_0 is incident on the boundary between two media A and B, as illustrated in Fig. 4.1.

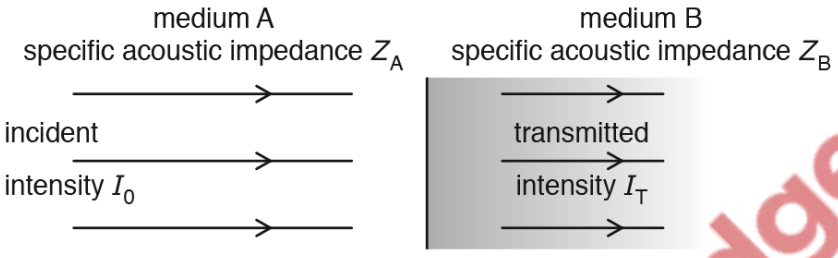

Fig. 4.1

The two media A and B have specific acoustic impedances Z_A and Z_B respectively. The intensity of the beam transmitted through the boundary is I_T.

State how the ratio

$$\frac{\text{intensity } I_T \text{ of transmitted beam}}{\text{intensity } I_0 \text{ of incident beam}}$$

depends on the relative magnitudes of Z_A and Z_B.

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.....[2]

(c) The linear absorption (attenuation) coefficient μ of medium B is $23\,\text{m}^{-1}$.

Calculate the thickness of medium B required to reduce the intensity of the ultrasound beam to 34% of its initial intensity in medium B.

thickness = ... m [3]

[Total: 7]

126. 9702_w19_qp_42 Q: 5

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

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..... [2]

(ii) The density of a sample of bone is $1.8\,g\,cm^{-3}$ and the speed of ultrasound in the bone is $4.1 \times 10^{3}\,m\,s^{-1}$.

Calculate the specific acoustic impedance Z_B of the sample of bone.

Z_B = ... $kg\,m^{-2}\,s^{-1}$ [1]

(b) A parallel beam of ultrasound passes normally through a layer of fat and of muscle, as illustrated in Fig. 5.1.

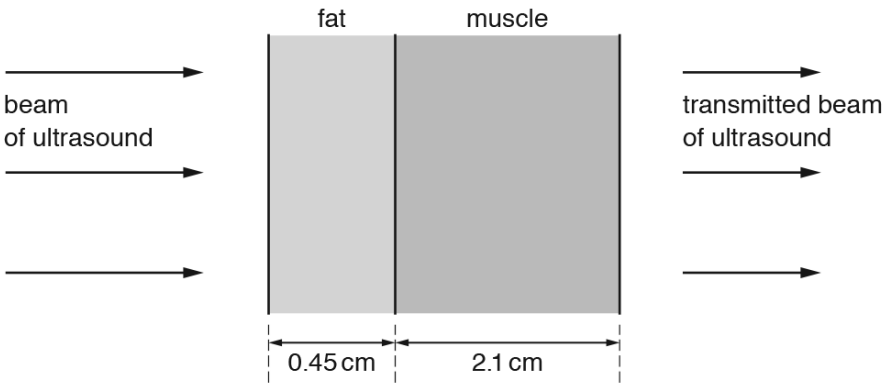

Fig. 5.1 (not to scale)

The fat has thickness 0.45 cm and the muscle has thickness 2.1 cm.

Data for fat and for muscle are given in Fig. 5.2.

	specific acoustic impedance $Z / 10^6\,\text{kg m}^{-2}\,\text{s}^{-1}$	linear attenuation (absorption) coefficient μ / cm^{-1}
fat	1.3	0.24
muscle	1.7	0.23

Fig. 5.2

The intensity reflection coefficient α at a boundary between two media of specific acoustic impedances Z_1 and Z_2 is given by the expression

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

Calculate the fraction of the intensity of the ultrasound that is **transmitted** through the boundary between the fat and the muscle.

fraction transmitted = ... [1]

(c) **(i)** State what is meant by *attenuation* of an ultrasound wave.

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..... [2]

(ii) Data for linear attenuation coefficients are given in Fig. 5.2.

Determine the ratio

$$\frac{\text{intensity of ultrasound transmitted through the medium}}{\text{intensity of ultrasound entering the medium}}$$

for:

1. the layer of fat of thickness 0.45 cm

ratio = ...

2. the layer of muscle of thickness 2.1 cm.

ratio = ...
[3]

(d) Use your answers in **(b)** and **(c)(ii)** to determine the fraction of the intensity entering the layer of fat that is transmitted through the layer of muscle.

fraction transmitted = ... [1]

[Total: 10]

127. 9702_m18_qp_42 Q: 5

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

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(b) **(i)** Define *specific acoustic impedance*.

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(ii) Two media have specific acoustic impedances of Z_1 and Z_2.

The magnitudes of the acoustic impedances may be almost equal or very different.
State how these differences affect the intensity reflection coefficient at the boundary between the two media.

$Z_1 \approx Z_2$ .....

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$Z_1 \gg Z_2$ or $Z_1 \ll Z_2$ .....

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[2]

[Total: 10]

128. 9702_s18_qp_41 Q: 4

Piezo-electric transducers are used for the generation of ultrasonic waves.

(a) State one other use, apart from in ultrasound, of piezo-electric transducers.

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.....[1]

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

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[Total: 7]

129. 9702_s18_qp_43 Q: 4

Piezo-electric transducers are used for the generation of ultrasonic waves.

(a) State one other use, apart from in ultrasound, of piezo-electric transducers.

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.....[1]

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

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[Total: 7]

130. 9702_w18_qp_41 Q: 4

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

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(b) **(i)** Define *specific acoustic impedance*.

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(ii) The fraction of the incident intensity of an ultrasound beam that is reflected at a boundary between two media depends on the specific acoustic impedances Z_1 and Z_2 of the media.

Discuss qualitatively how the relative magnitudes of the two specific acoustic impedances affect the reflected intensity.

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[Total: 10]

131. 9702_w18_qp_43 Q: 4

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

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(b) **(i)** Define *specific acoustic impedance*.

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.....[2]

(ii) The fraction of the incident intensity of an ultrasound beam that is reflected at a boundary between two media depends on the specific acoustic impedances Z_1 and Z_2 of the media.

Discuss qualitatively how the relative magnitudes of the two specific acoustic impedances affect the reflected intensity.

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[Total: 10]

132. 9702_m17_qp_42 Q: 4

Explain the main principles of the **generation** of ultrasound waves for medical use.

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[Total: 4]

133. 9702_s17_qp_42 Q: 4

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

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(b) A parallel beam of ultrasound has intensity I_0 as it enters a muscle of thickness 4.6 cm, as illustrated in Fig. 4.1.

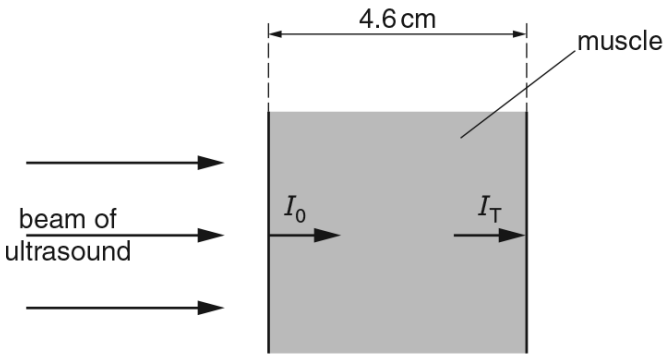

Fig. 4.1

The intensity of the beam just before it leaves the muscle is I_T.
The ratio I_0/I_T is found to be 2.9.

Calculate the linear attenuation (absorption) coefficient μ of the ultrasound in the layer of muscle.

μ = ... cm^{-1} [3]

[Total: 9]

134. 9702_w17_qp_42 Q: 4

(a) Explain the principles behind the **generation** of ultrasound waves for diagnosis in medicine.

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(b) Ultrasound frequencies as high as 10 MHz are used in medical diagnosis.
Suggest one advantage of the use of high-frequency ultrasound rather than lower-frequency ultrasound.

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[Total: 6]

135. 9702_m16_qp_42 Q: 6

A parallel beam of ultrasound is incident normally on the surface of a layer of fat of thickness 1.1 cm, as shown in Fig. 6.1.

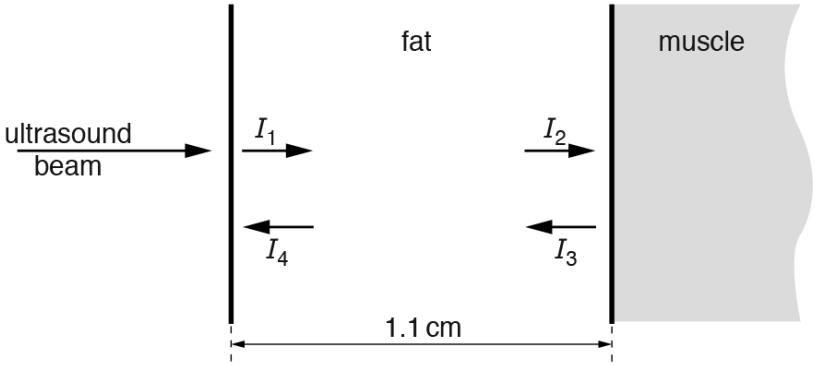

Fig. 6.1

For the ultrasound,
I_1 is the intensity just after entering the surface of the fat layer,
I_2 is the intensity incident on the fat-muscle boundary,
I_3 is the intensity reflected from the fat-muscle boundary,
I_4 is the intensity received back at the surface of the fat layer.

Some data for the fat are given in Fig. 6.2.

specific acoustic impedance Z	$1.4 \times 10^6\,\text{kg m}^{-2}\,\text{s}^{-1}$
density ρ	$940\,\text{kg m}^{-3}$
absorption (attenuation) coefficient μ	$48\,\text{m}^{-1}$

Fig. 6.2

(a) Calculate the time interval between a short pulse of ultrasound initially entering the layer of fat and then returning back to the surface of the fat layer.

time = ... s [3]

(b) Calculate the ratio $\frac{I_2}{I_1}$.

ratio = ...[2]

(c) Intensity I_4 is 0.33% of intensity I_1.

Determine the ratio $\frac{I_3}{I_2}$.

ratio = ...[2]

(d) The specific acoustic impedance of the muscle is greater than that of the fat.

State the effect, if any, on the value of the ratio $\frac{I_3}{I_2}$ of an increase in the difference between the specific acoustic impedance of the muscle and that of the fat.

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.....[1]

[Total: 8]

136. 9702_w16_qp_42 Q: 5

Ultrasound may be used to obtain information about internal body structures.

(a) Suggest why the ultrasound from the transducer is pulsed.

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.....[2]

(b) **(i)** State what is meant by *specific acoustic impedance*.

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(ii) A parallel beam of ultrasound of intensity I_0 is incident normally on the boundary between two media, as shown in Fig. 5.1.

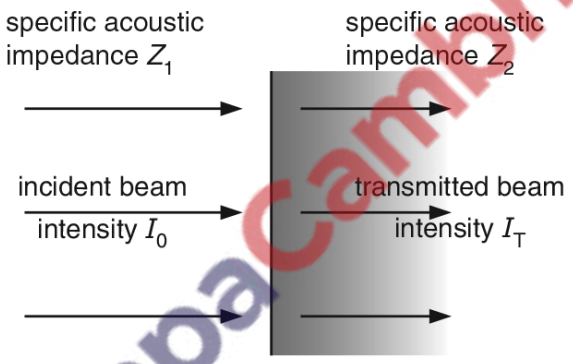

Fig. 5.1

The media have specific acoustic impedances Z_1 and Z_2.
The intensity of the ultrasound beam transmitted across the boundary is I_T.

Explain the significance of the magnitudes of Z_1 and of Z_2 on the ratio I_T/I_0.

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[Total: 6]