

0	1	.	1
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An endoscope is used to view an area inside the body. The endoscope contains two bundles of optical fibres.

Name each bundle and explain its use in the process.

[4 marks]

Bundle 1

Bundle 2



0 1 . 2

A single optical fibre is placed in air. The optical fibre has a core surrounded by cladding. The critical angle is 75° at the core-cladding boundary.

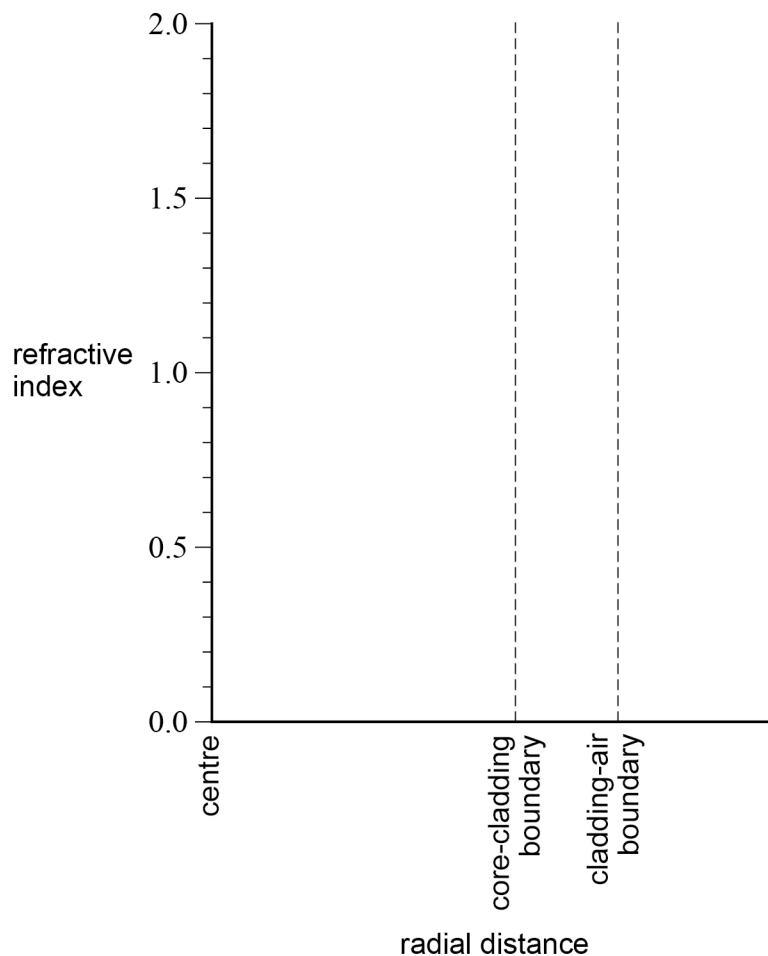
Complete **Figure 1** to show how the refractive index varies with radial distance from the centre of the core to the air surrounding the fibre.

Your answer should be supported by a suitable calculation.

refractive index of core = 1.6

[2 marks]

Figure 1



Question	Answers	Additional Comments/Guidelines	Mark
01.1	Coherent bundle – fixed arrangement of fibres at each end ✓ Used to transmit image (from inside the body to the viewer) ✓ Non-coherent bundle – random arrangement of fibres ✓ Used to transmit light into the body / to illuminate (area under investigation) ✓	Name of bundle plus either point for first mark If no marks awarded, give 1 mark if both bundles have been named.	4
01.2	Core at 1.6; cladding 1.55 ie half way between their core and 1.5 ✓ series of clear horizontal steps with air at 1.0 ✓	Although they are told to do a calculation, give the mark on the diagram for 1.55 even if no calc shown If no marks awarded for drawing, then give 1 mark for correct calculation.	2
Total			6

0 2

Ultrasound is commonly used in medical procedures.

0 2 . 1

An ultrasound A-scan is used to find the length l of an eye as shown in **Figure 6**. **Figure 7** shows the simplified A-scan for the eye. A short pulse of ultrasound is transmitted at time $t = 0$

The average speed of ultrasound in the eye = 1560 m s^{-1} .

Figure 6

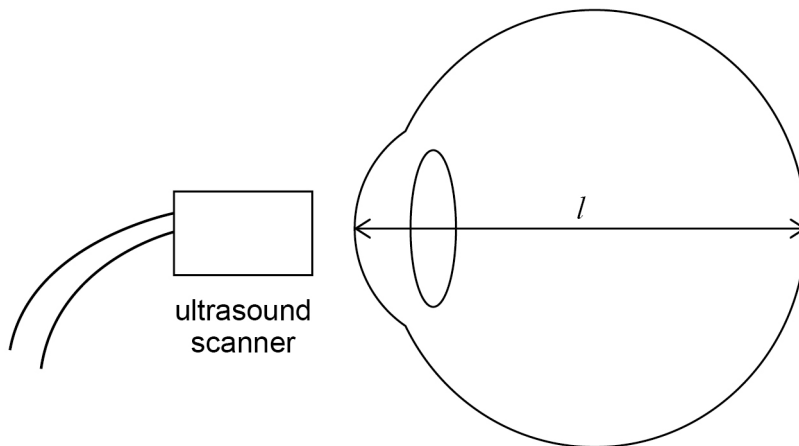
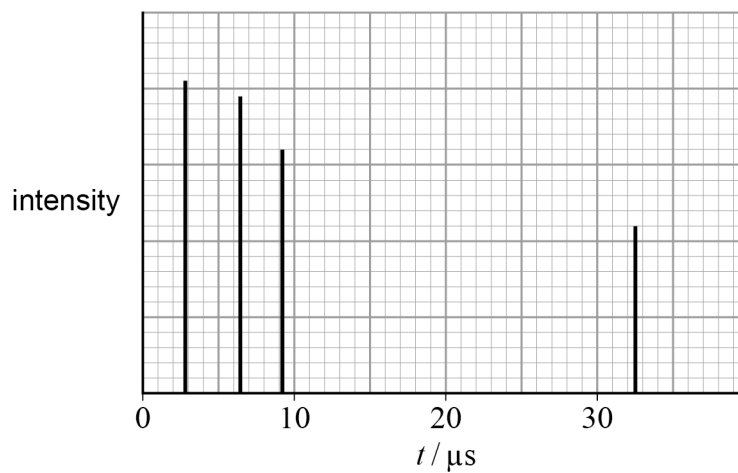


Figure 7



Calculate l .

[3 marks]

$l =$ _____ m



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box*

0	2	.	2
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Amniocentesis is a procedure where a tube is inserted into a uterus to remove some cells and fluid from around a foetus. For the procedure to be carried out safely the positions of the needle, foetus and placenta must be determined accurately.

Discuss whether an A-scan or a B-scan should be used for amniocentesis.

In your answer, you should:

- outline the differences between an A-scan and a B-scan
- describe the advantages and disadvantages of each type of scan
- explain why your chosen scan should be used for this procedure.

[6 marks]

Question 4 continues on the next page

Turn over ►



Question	Answers	Additional Comments/Guidelines	Mark
02.1	$t = (32.5 - 3.0) \times 10^{-6} (= 29.5 \times 10^{-6} \text{ s}) \checkmark$ $s = vt = 1560 \times 29.5 \times 10^{-6} \checkmark (= 46 \times 10^{-3} \text{ m})$ Eyeball length = $\frac{46 \times 10^{-3}}{2} = 23 \times 10^{-3} \checkmark \text{ m}$	1 st mark is for correctly using the timing from the first and last reflection. ecf for 2 nd and 3 rd mark if wrong reflections used. 3 rd mark is for dividing by 2 and is independent	1 1 1

02.2	The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.		Difference between the A-scan and B-scan - Multiple sensors in B-scan as opposed to one sensor in A-scan - A scan intensity determines amplitude - B scan intensity determines brightness Advantages/Disadvantages A-scan - An A-scan only produces a graph - Good for accurately determining distances (where a limited number of surfaces lie along a straight line) - With complex structures it is difficult to identify which surface produces which echo - The structures may not lie along one line B-scan - B-scan produces a picture - A 2D cross section is obtained rather than a single line - Allows the structures to be identified more easily - Allows features that are not along one line to be identified - Harder to accurately determine distances along a straight line Suitability Why a B-scan is suitable - Multiple features of needle, foetus, uterus and placenta require an image to identify Why an A-scan is not suitable - Multiple features of needle, foetus, uterus and placenta - are complex structures - which do not lie along a straight line - cannot be easily identified on a graph	6
	Mark	Criteria		
	6	Select the B-scan, Cover all 3 areas in detail, referring to both scans in at least 2 areas, without error. It must relate to amniocentesis.		
	5	Select the B-scan, Cover all 3 areas, referring to both scans in at least 2 areas. May contain minor errors. It must relate to amniocentesis.		
	4	choose the B-scan Cover at least 2 areas, referring to both scans Or cover all 3 areas referring to one scan		
	3	Cover at least 2 areas referring to one scan Or Cover 1 area referring to both scans in detail It may or may not choose the B-scan.		
	2	Cover 1 area referring to both scans It may or may not choose the B-scan		
	1	Cover 1 area referring to one scan. It may or may not choose the B-scan		
	0	No relevant comments		

0 3 . 2

Ultrasound of frequency 1.0 MHz is used to scan a person's liver.

Estimate the resolution of the scan.

speed of sound in liver tissue = 1600 m s^{-1}

[1 mark]

resolution = _____ mm

Question 4 continues on the next page

Turn over ►



0 3 . 3

Ultrasound travels from a transducer through the chest wall to an air pocket inside the lung. From the air pocket, the ultrasound is then incident on lung tissue.

Calculate the percentage of the incident ultrasound intensity that is transmitted into the lung tissue.

speed of sound in lung tissue = 1580 m s^{-1}

density of lung tissue = 1075 kg m^{-3}

speed of sound in air = 330 m s^{-1}

density of air = 1.3 kg m^{-3}

[4 marks]

percentage = _____ %



0	3	.	4
---	---	---	---

Discuss whether an ultrasound scan would be suitable to investigate a tumour inside a lung.

[2 marks]

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13

Question	Answers	Additional comments/Guidelines	Mark	AO																
03.1	The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the ‘Mark Scheme Instructions’ document should be used to assist in marking this question. <table><tr><th>Mark</th><th>Criteria</th></tr><tr><td>6</td><td>All 3 areas covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.</td></tr><tr><td>5</td><td>All 3 areas covered at least 2 in detail. Whilst there will be gaps, there should only be an occasional error.</td></tr><tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.</td></tr><tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr><tr><td>2</td><td>Only one area discussed, or makes a partial attempt at two areas.</td></tr><tr><td>1</td><td>None of the three areas covered without significant error.</td></tr><tr><td>0</td><td>No relevant analysis.</td></tr></table>	Mark	Criteria	6	All 3 areas covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.	5	All 3 areas covered at least 2 in detail. Whilst there will be gaps, there should only be an occasional error.	4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.	3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.	2	Only one area discussed, or makes a partial attempt at two areas.	1	None of the three areas covered without significant error.	0	No relevant analysis.	Points to consider How an ultrasound pulse is produced: • alternating potential difference applied across the crystal • causes crystal to expand and contract • creating pressure waves in the crystal / plastic membrane • frequency of alternating pd equal to that of crystal / resonant frequency of crystal • which is above 20 kHz. How the ultrasound reflection is detected: • pressure wave in the crystal • causes crystal to expand and contract • which produces a potential difference across the crystal. The same transducer acts as receiver as well as transmitter: • short application of ac to produce short pulse • use of backing material to damp and stop vibration of crystal • crystal must stop vibrating before reflection reaches it.	6	2× AO1.1a 4× AO2.1b
Mark	Criteria																			
6	All 3 areas covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.																			
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2	Only one area discussed, or makes a partial attempt at two areas.																			
1	None of the three areas covered without significant error.																			
0	No relevant analysis.																			

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	$\lambda = \frac{c}{f} = \frac{1600}{1.0 \times 10^6} = 0.0016$ Resolution = 1.6 mm ✓	Allow 1 sf answer of 2 mm	1	AO2.1b
03.3	$Z_1 = \rho c = 1.3 \times 330 (= 429)$ or $Z_2 = \rho c = 1075 \times 1580 (= 1.70 \times 10^6)$ ✓ $\left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2 = \left(\frac{1.70 \times 10^6 - 4.29 \times 10^2}{1.70 \times 10^6 + 4.29 \times 10^2}\right)^2 \checkmark = 0.999 \checkmark$ $100 - 99.9 = 0.1\%$ ✓	Allow ecf Allow 1 sf	4	AO2.1b
03.4	Not suitable as all/most/99.9% of the ultrasound would be reflected ✓ when going from the air inside the lungs to the lung tissue ✓	Allow correct argument based around transmission MP2 is for the direction where most is reflected.	2	AO3.1a
Total			13	

0 4

Figure 2 shows scanned images of three different human heads. Each image used **one** of the following scanning techniques:

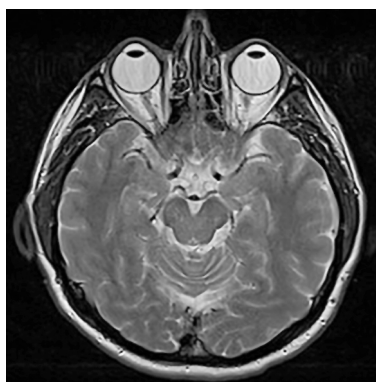
- magnetic resonance (MR)
- CT
- ultrasound
- PET.

Figure 2

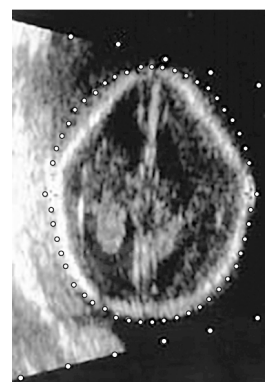
A



B



C



Identify the scanning technique used for each image.

Go on to explain how the features of each image enabled you to identify the type of scan.

[4 marks]

A: Scanning technique _____

Explanation _____

B: Scanning technique _____

Explanation _____

C: Scanning technique _____

Explanation _____

4

Turn over ►



Question	Answers	Additional comments/Guidelines	Mark	AO
04	Correct identification of all three A: CT scanner, B: MR scanner, C: Ultrasound scanner ✓ A: good picture of bone / bright picture of bone / lacking detail on soft tissue (eg eyes, brain) ✓ B: highest resolution / good (detailed/bright) image of soft tissue (eg eyes, brain) / dim picture of bone ✓ C: low resolution / image shows external boundaries (eg uterus) / lack of detail inside skull ✓	Allow CAT for CT and MRI for MR	4	AO3
Total			4	

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0 5 . 1

State the purpose of the magnetic field in a magnetic resonance scanner.

[1 mark]

0 5 . 2

Describe the role of the radio frequency pulses in a magnetic resonance scanner.

[2 marks]

3



Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	Align spins of protons / hydrogen nuclei ✓	Do NOT allow hydrogen atoms Allow causes protons / hydrogen nuclei to precess around magnetic field / in one direction Do NOT allow causes protons to spin	1	AO1
Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	(radio frequency photons) excite protons ✓ Flip the (spin of) protons ✓ (When pulse stopped) protons emit radio frequency signals when they relax ✓	MAX 2 Condone RF Condone atoms for protons Condone move or make into antialignment with magnetic field for MP2	2	2 x AO1
Total			3	

0	6
---	---

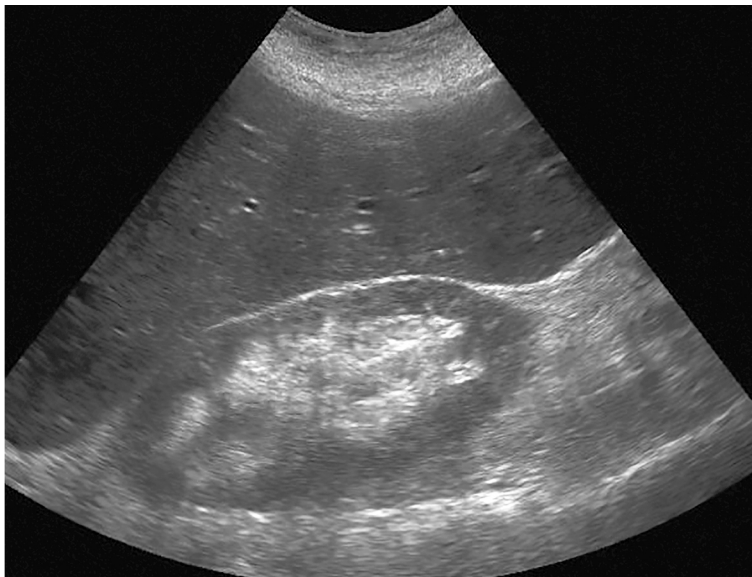
Different ultrasound techniques are used to investigate the health of a patient's kidneys.

0	6
---	---

1

Figure 3 shows the results of an ultrasound scan of a kidney using one technique.

Figure 3



Identify the type of ultrasound scan used to produce **Figure 3**.

Explain your answer.

[1 mark]

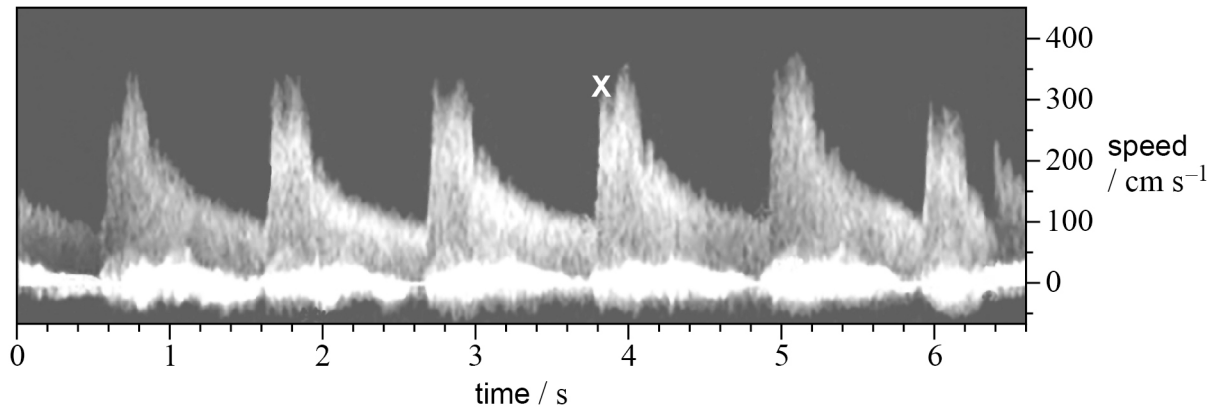
Turn over ►



Another ultrasound technique is used to measure the speed of blood flow in one of the kidney's blood vessels.

Figure 4 shows an image formed using this technique. It shows how the speed of flow through the blood vessel varies with time.
Point **X** shows this speed at one instant of time.

Figure 4



0 6 . 2

Determine the patient's heart rate in beats per minute.

[3 marks]

heart rate = _____ beats per minute



06.3

An ECG was made for the patient in Question 06.2.

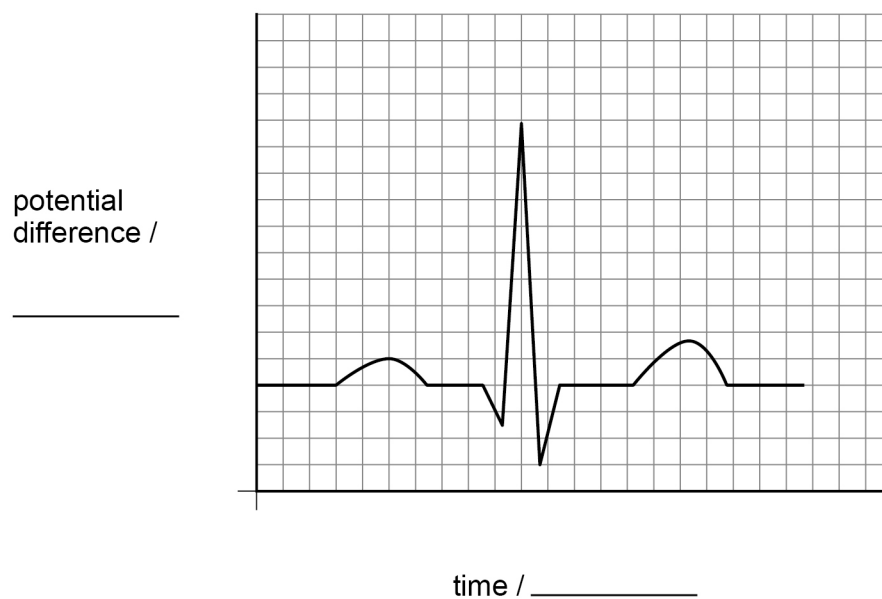
Figure 5 shows one heartbeat from the ECG.

Annotate **Figure 5** to show:

- units on both axes
- scales on both axes
- point **Y** that corresponds to point **X** on **Figure 4**.

[4 marks]

Figure 5



Turn over ►



0 6 . 4

A backing gel is used between an ECG pad and the skin of the patient. The gel is sticky. This property ensures that the pad is securely attached to the skin.

Explain:

- one other reason why the backing gel is needed
- one other property of the backing gel
- how the skin is prepared for the pad to be applied.

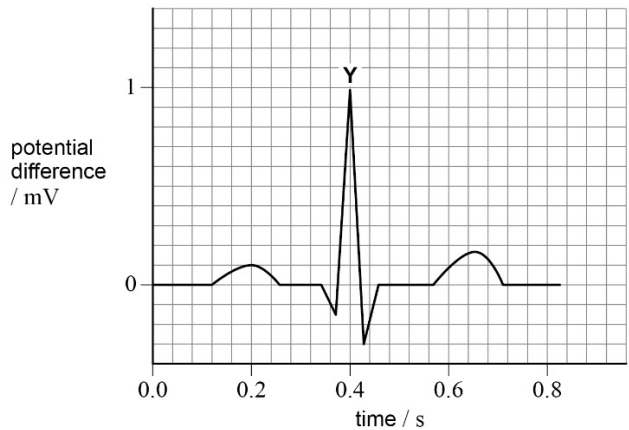
[3 marks]

11



Question	Answers	Additional comments/Guidelines	Mark	AO
06.1	B scan because it is an image (rather than a graph) ✓	Allow 'brightness scan' for B scan	1	1 × AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
06.2	Determines accurate time for a whole number of heartbeats OR $\frac{\text{their number of beats}}{\text{their time}}$ OR $\frac{\text{their time}}{\text{their number of beats}}$ OR converts their bps to bpm ✓ Evidence of T taken from 3, 4 or 5 heartbeats OR repeat and mean for at least three measurements ✓ Leading to answers that round to 56 or 57 bpm ✓	Accept correct use of frequency for MP2	3	1 × AO2 1 × AO3 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
06.3	mV on y-axis and s on x-axis ✓ values of y-axis with at least 2 values labelled, consistent with 0 at start of line and 1 at peak ✓ values on x-axis with end point between 0.55 and 1.0 s. At least three evenly spaced values seen including 0 ✓ position of Y indicated to be within one square of the highest peak ✓	 Allow for alternative correct units and values eg 0.001 V, time of 400–750 ms For MP3 ticks on x-axis required; do not accept awkward scales	4	3 × AO1 1 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
06.4	Why backing is needed: Idea that gels improves electrical contact ✓ Property of backing: gel should have low (electrical) resistance or non-irritating to skin or shouldn't react to chemicals produced by skin ✓ How skin is prepared: skin is shaved / rubbed with abrasive paper/ hair removed ✓	For MP2 do not allow reference to or implication of acoustic resistance / impedance MP3 - allow skin is dried or cleaned	3	2 × AO1 1 × AO2
Total			11	

07.1

Name the two types of optical fibre bundle used in an endoscope.

Go on to discuss whether the optical fibres in either of these bundles require cladding.

[4 marks]

07.2

Modal and material dispersion can cause problems in fibre-optic communications.

Discuss why the methods used to reduce modal and material dispersion are not required in an endoscope.

In your answer you should:

- describe the methods used to reduce dispersion in an optical fibre used for communication
- explain why the methods are not required in an endoscope
- explain how using these methods in an endoscope would affect its function.

[6 marks]



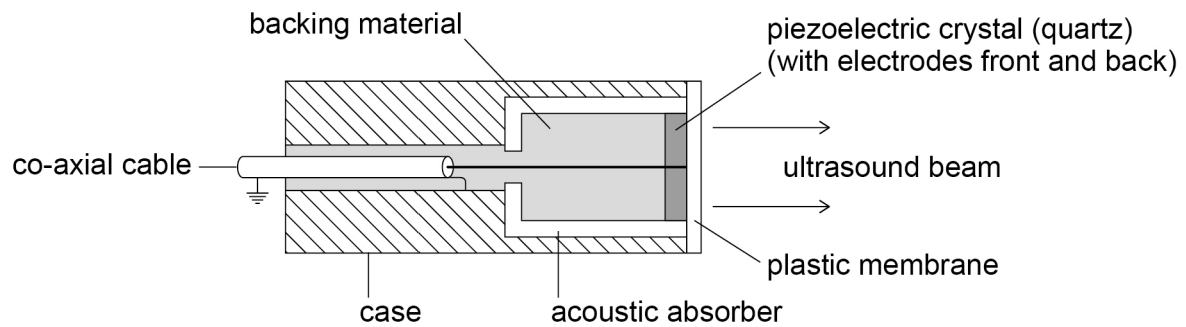
Question	Answers	Additional comments/Guidelines	Mark	AO
07.1	Name coherent and non-coherent bundle ✓₁ Coherent bundle transmits images OR non-coherent bundle transmits light for illumination/ into the body ✓₂ Bundle that transmits light for illumination requires no cladding ✓₃ Cladding is required in bundle that transmits images so that light does not pass from one fibre to another (which would destroy the image) ✓₄	✓₁ Accept 'incoherent' ✓₂ 'transmits light' insufficient for function of non-coherent bundle ✓₃ and ✓₄ are for linking the function to the requirement for cladding and can be awarded if names are missing, incorrect or mixed up so long as function clear. ✓_{3 4} 1 mark for stating coherent need cladding and non-coherent do not	4	2×AO1 2×AO3

Question	Answers	Additional comments/Guidelines	Mark	AO																
07.2	The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer. Guidance provided in section 3.10 of the ‘Mark Scheme Instructions’ document should be used to assist in marking this question. <table><tr><th>Mark</th><th>Criteria</th></tr><tr><td>6</td><td>All three areas covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.</td></tr><tr><td>5</td><td>All three areas covered, at least two in detail. Whilst there will be gaps, there should only be an occasional error.</td></tr><tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.</td></tr><tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr><tr><td>2</td><td>Only one area discussed, or makes a partial attempt at two areas.</td></tr><tr><td>1</td><td>Only one area covered and that partially.</td></tr><tr><td>0</td><td>No relevant comments.</td></tr></table>	Mark	Criteria	6	All three areas covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.	5	All three areas covered, at least two in detail. Whilst there will be gaps, there should only be an occasional error.	4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.	3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.	2	Only one area discussed, or makes a partial attempt at two areas.	1	Only one area covered and that partially.	0	No relevant comments.	In each area, a partial response covers one bullet point, a detailed response requires two. Methods used to reduce dispersion • Mentions either mono-mode fibre (mod), monochromatic light (mat), small difference in refractive indices of core and cladding (mod) or repeaters (both) • Mentions two methods with at least one linked to correct type of dispersion (name or description) Why the methods are not required • Short distance of the endoscope • Reason given for why this results in insignificant dispersion • No pulse broadening due to analogue signal • Idea that function of non-coherent bundle is unaffected by dispersion • Comparison of (lower) data transfer rate for endoscope compared to high speed data transfer for communications. Means dispersion is not noticeable How the methods affect the function • Refractive index of core close to refractive index of cladding – lots of light escapes. Reduces intensity of image (which makes it harder to see) • Mono-mode fibre reduces amount of light transmitted. Reduces intensity of image • Monochromatic light – image is monochrome (which makes diagnosis harder) • Narrower fibres therefore more fibres can fit in the bundle therefore better resolution • Discussion of impact of any one of these changes on diagnosis/ treatments • Repeater would make the endoscope too wide to go inside patient.	6	2×AO1 2×AO2 2×AO3
Mark	Criteria																			
6	All three areas covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.																			
5	All three areas covered, at least two in detail. Whilst there will be gaps, there should only be an occasional error.																			
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2	Only one area discussed, or makes a partial attempt at two areas.																			
1	Only one area covered and that partially.																			
0	No relevant comments.																			
Total			10																	

0 8 . 1

Figure 2 shows a transducer used in a medical ultrasound scanner.

Figure 2



Explain why a backing material is used.

[2 marks]



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0 8 . 2

A beam of ultrasound is transmitted from muscle into bone.

Calculate the percentage of the incident intensity that is transmitted.

acoustic impedance of bone = $5.3 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$

density of muscle = 1100 kg m^{-3}

speed of ultrasound in muscle = 1600 m s^{-1}

[3 marks]

percentage = _____ %

5



Question	Answers	Additional comments/Guidelines	Mark	AO
08.1	To damp the vibrations (of the piezoelectric crystal) (after the pulse has been transmitted) ✓ To allow the crystal to serve as receiver (as well as transmitter)/ so reflected and transmitted pulses remain separate (at the transducer)/ so pulses can be short ✓		2	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
08.2	Max 2 from ✓✓ (Muscle $Z = \rho c =$) 1100×1600 OR 1.76×10^6 ($\text{kg s}^{-1} \text{m}^{-2}$) ✓_a Use of $\left(\frac{I_r}{I_i} = \right) \left(\frac{Z_2 - \text{their } Z_1}{Z_2 + \text{their } Z_1}\right)^2$ to find reflected ratio OR 0.25 ✓_b Conversion of their ratio to % and subtraction from 100 ✓_c 75 (%) ✓	✓_b Accept Z_1 and Z_2 in either order Expect $\left(\frac{5.3 \times 10^6 - 1.76 \times 10^6}{5.3 \times 10^6 + 1.76 \times 10^6}\right)^2$ do not accept use of ρ or c as Z Calc value 74.85815631	3	AO2
Total			5	