

Ultrasound

Mark Scheme



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1. When we hear the word ultrasound most of us think about the scans of a baby in the womb, but ultrasound has a huge range of other fascinating uses.

- a. What type of wave is ultrasound, and what is its typical frequency?

A – is the only correct answer.	1 mark
	Total: 1 mark

- b. The graphs below show the displacement of particles over time for sound waves from three different sources: **wave X**, **wave Y**, and **wave Z**.

D – is the only correct answer.	1 mark
	Total: 1 mark

- c. Ultrasound gel is placed on a patient's skin before a scan. When the ultrasound wave travels from the gel into the patient's skin, the wavelength of the wave decreases.

A – is the only correct answer.	1 mark
	Total: 1 mark

- d. A bat is hunting in the dark and emits an ultrasound pulse to locate a flying moth. The bat hears the echo from the moth exactly 0.02 seconds later.

A – is the only correct answer.	1 mark
	Total: 1 mark

- e. Why is ultrasound used instead of X-rays to produce images of unborn babies?

C – is the only correct answer.	1 mark
	Total: 1 mark

- f. Dolphins use ultrasound clicks to navigate and hunt fish underwater.

B – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 6 marks)

2. A team of climate scientists are working in Antarctica. They're using an ultrasound scanner to measure the thickness of a large glacier to monitor how much it is melting.

The scanner is placed on the surface of the ice and sends an ultrasound pulse downwards towards the solid rock beneath the glacier. The figure below shows the scientists at work.



- a. What is ultrasound?

<u>Sound (waves) with a frequency greater than 20,000 Hz (or 20 kHz).</u>	1 mark
	Total: 1 mark

- b. Explain one advantage of using ultrasound to measure the thickness of the glacier, rather than physically drilling a hole through the ice to the rock.

<u>An explanation to include the following:</u>	
<u>One advantage and a linked explanation.</u> Award 1 mark for each.	
Advantage: It is non-destructive. Linked explanation: so it does not damage the ice/glacier.	
Advantage: It is much quicker / requires less energy. Linked explanation: because they do not have to bring heavy drilling equipment / bore through thick ice.	
	Total: 2 marks

- c. The scanner emits a pulse of ultrasound into the ice. The echo from the solid rock at the bottom of the glacier is detected by the scanner 0.15 seconds later. The speed of sound in the ice is 3980 m/s.

Calculate the thickness of the glacier.

Distance = $3980 \times 0.15 = 597$ m	1 mark
Half of the distance as this is an echo. $597 \div 2$	1 mark
Final distance: 298.5 m	1 mark
	Total: 3 marks

- d. The ultrasound pulse used by the scientists has a frequency of 40 kHz.
Calculate the wavelength of the ultrasound wave in the ice.

Converts kHz to Hz: 40 kHz = 40,000 Hz	1 mark
Rearranges the wave equation and substitutes the correct values: $\lambda = 3980 \div 40,000$	1 mark
$\lambda = 0.0995 \text{ m}$	1 mark
	Total: 3 marks

- e. The scientists view the ultrasound signal on an oscilloscope screen.

They notice that the peak representing the returning echo has a much smaller amplitude than the peak of the original pulse emitted by the scanner.

Suggest **two** reasons why the returning wave has a lower amplitude.

Any two of the following:	
- Some of the wave's energy is absorbed by the ice. - Some of the wave is transmitted into the rock (it is only partially reflected at the boundary). - The wave spreads out / diverges / scatters as it travels.	
	Total: 2 marks

(Total for Question 2 is 11 marks)

3. A fishing boat uses an echo-sounder to measure the depth of the sea bed and to find shoals of fish.
- a. As shown in the diagram, the boat is situated in water where the sea bed is exactly **12 m** below the echo-sounder.

Calculate the time it takes for an ultrasound pulse to travel to the sea bed and return to the boat.

Total distance = $12 \times 2 = 24 \text{ m}$	1 mark
Time = distance $\div$ speed Time = $24 \div 1500$	1 mark
Time = 0.016 seconds	1 mark
	Total: 3 marks

The boat moves to a new location.

The echo-sounder now detects an echo returning after just **0.006 seconds**.

The captain realises this is an echo bouncing off a large shoal of fish, rather than the sea bed.

- b. Calculate the depth of the shoal of fish below the boat.

Total distance travelled = $1500 \times 0.006 = 9 \text{ m}$	1 mark
The student halves the total distance to find the depth.	1 mark
$9 \div 2 = 4.5 \text{ m}$	1 mark
	Total: 3 marks

- c. The ultrasound waves used by this echo-sounder have a frequency of 50 kHz.
Calculate the wavelength of these ultrasound waves in the seawater.

(Use the equation: wave speed = frequency $\times$ wavelength)

Converts kHz to Hz: $50 \text{ kHz} = 50,000 \text{ Hz}$	1 mark
$\lambda = 1500 \div 50,000$	1 mark
$\lambda = 0.03 \text{ m}$	1 mark
	Total: 3 marks

- d. State **one** reason why it is better to use ultrasound rather than normal, audible sound waves to detect objects like fish underwater.

Any one of the following:	
• Ultrasound has a shorter wavelength, so it reflects off smaller objects (like fish) / gives a higher resolution image. • Ultrasound has a higher frequency, so the pulses can be shorter/more precise. • It cannot be heard by humans, so it does not annoy the crew on the boat.	
	Total: 1 mark

(Total for Question 3 is 10 marks)

4. A patient has injured their knee playing football.
The doctor suspects they have a tear in their meniscus, which is a pad of cartilage inside the knee joint.



- a. The ultrasound probe emits sound waves with a time period of 0.0005 milliseconds.
Calculate the frequency of the ultrasound waves in Hertz (Hz).

Converts milliseconds to seconds (divides by 1000): $0.0005 \text{ ms} = 0.0000005 \text{ s}$	1 mark
Frequency ($f = 1 \div T$): $1 \div 0.0000005$ $f = 2,000,000 \text{ (Hz)}$	1 mark
	Total: 2 marks

- b. The ultrasound waves pass into the knee tissue.
The wavelength of the waves in the tissue is 0.77 millimetres (mm).
Use your answer to part (a) to calculate the wave speed of the ultrasound through the knee.

Converts millimetres to metres (divides by 1000): $0.77 \text{ mm} = 0.00077 \text{ m}$	1 mark
$v = f \times \lambda$ $v = 2\,000\,000 \times 0.00077$ $v = 1540 \text{ m/s}$	1 mark
	Total: 2 marks

- c. A pulse of ultrasound reflects off the tear in the meniscus cartilage.
The echo is detected by the probe exactly 0.00006 seconds after it was emitted.
Calculate the distance (depth) from the probe to the tear in the cartilage.

Uses distance = speed $\times$ time (with their speed from part b) to find total distance: $\text{distance} = 1540 \times 0.00006$ $\text{distance} = 0.0924 \text{ m}$	1 mark
Recognises this is an echo and halves the total distance: $0.0924 \div 2$ $\text{distance} = 0.0462 \text{ (m)}$	1 mark
	Total: 2 marks

(Total for Question 4 is 6 marks)

5. An aerospace engineer is using ultrasound for non-destructive testing on a titanium jet engine blade. They are checking the blade for internal micro-cracks.



A pulse of ultrasound is fired into the metal and reflects off a hidden crack.

- The crack is located at a depth of 5.4 cm inside the blade.
- The returning echo is detected by the probe 0.02 milliseconds (ms) after the pulse was emitted.
- The wavelength of the ultrasound waves in the titanium is 120 mm.

Calculate the frequency of the ultrasound wave being used by the engineer.

Marking guidance	
Award full 6 marks for the correct final answer of 45,000 (or 4.5×10^4), even if no working out is shown	
Allow error carried forward (ECF): If a student makes an early mistake (e.g., a unit conversion error) but uses their incorrect value correctly in the subsequent physics equations, they must be awarded the marks for those later steps.	

Indicative content:	
Distance conversion & echo concept: Converts 5.4 cm to metres AND doubles it to account for the echo (journey to the crack and back). $\text{Distance} = 0.054 \text{ m} \times 2 = 0.108 \text{ m}$	1 mark
Converts 0.02 milliseconds to seconds (divides by 1000). $\text{Time} = 0.00002 \text{ s (or } 2 \times 10^{-5} \text{ s)}$	1 mark
Uses $v = s / t$ with their distance and time values. $\text{Speed} = 0.108 \div 0.00002 = 5400 \text{ (m/s)}$	1 mark
Converts 120 mm to metres (divides by 1000). $\text{Wavelength} = 0.12 \text{ m}$	1 mark
Equation rearrangement & substitution: $f = v \div \lambda$ $f = 5400 \div 0.12$	1 mark
Final answer: $45\,000 \text{ Hz (or } 4.5 \times 10^4)$	1 mark
	Total: 6 marks

(Total for Question 5 is 6 marks)

6. A mother mouse communicates with her babies by emitting high-pitched ultrasound squeaks.



The ultrasound waves have a frequency of 85,000 Hz. The speed of sound in the air is 340 m/s.

- a. Calculate the wavelength of the ultrasound waves emitted by the mouse.

Recalls equation $\lambda = v \div f$ (or $v = f \times \lambda$)	1 mark
$\lambda = 340 \div 85,000$	1 mark
$\lambda = 0.004 \text{ (m)}$	1 mark
	Total: 3 marks

- b. Ultrasound is widely used in hospitals for scanning unborn babies.

State **two** other practical uses of ultrasound outside of medicine.

Any two from the following:	
- Echo-sounding / Sonar / mapping the seabed / finding fish. - Non-destructive testing / finding flaws or cracks in metal/materials. - Cleaning delicate items (e.g., jewellery, optical lenses). - Welding plastics together. - Animal training / dog whistles.	
	Total: 2 marks

- c. A doctor is trying to diagnose a patient's injury.

They must decide whether to use an ultrasound scan or an X-ray.

Compare and contrast the advantages of using ultrasound and X-rays for medical scans.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple relevant statements are made (e.g., "X-rays are dangerous, ultrasound is safe"), but the answer lacks detail and structure.
Level 2	3 - 4	A mostly correct comparison covering at least two areas (e.g., safety and uses). Some scientific terms are used, though there may be minor inaccuracies.
Level 3	5 - 6	A detailed and coherent comparison. The student accurately compares the physical properties, safety, and best uses of both wave types. Scientific terminology is used accurately.

Indicative content:	
Safety (advantages): • Ultrasound is non-ionising so it is safe (e.g., for babies). • X-rays are ionising radiation which can mutate DNA / damage cells / cause cancer. Imaging / uses (advantages): • Ultrasound is best for imaging soft tissues (organs, muscles) as it reflects at boundaries. • X-rays are best for imaging hard tissues (bones) because bones absorb X-rays while soft tissue lets them pass through. Wave properties (differences): • Ultrasound is a longitudinal/mechanical wave. • X-rays are transverse/electromagnetic waves.	
	Total: 6 marks

(Total for Question 6 is 11 marks)