IG.P7 Sound Waves and Ultrasound

EDEXCEL 4PH1 · Calculator allowed · about 50 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 State whether sound waves are longitudinal or transverse, in the context of sound travelling through air.

(Total for Question 1 is 1 mark)

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2 Explain why sound cannot be heard in a vacuum, using the idea of a medium for sound to travel.

(Total for Question 2 is 1 mark)

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3 State the typical audible frequency range for a healthy human ear, naming both the low and high frequency limits.

(Total for Question 3 is 1 mark)

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4 State the equation relating wave speed, frequency and wavelength and name each symbol, in the context of sound waves in air.

(Total for Question 4 is 2 marks)

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5 A tuning fork produces a sound of frequency 440 Hz in air where the speed of sound is 340 m/s. Calculate the wavelength of this sound in air.

(Total for Question 5 is 3 marks)

6 A sound source emits a steady tone at frequency 1000 Hz. State whether this frequency is within the typical human hearing range and explain your answer briefly.

(Total for Question 6 is 2 marks)

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7 An echo is used to measure the distance to a cliff face. A student stands at a lake shore and emits a loud sound. The echo is heard 2.4 s later. Using speed of sound in air as 340 m/s, calculate the distance from the student to the cliff face.

(Total for Question 7 is 3 marks)

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8 A bat emits ultrasonic pulses and measures echoes to locate prey. If the bat emits pulses at 50 kHz and the speed of sound in air is 340 m/s, calculate the wavelength of these ultrasonic pulses.

(Total for Question 8 is 3 marks)

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9 State the definition of ultrasound in terms of frequency, naming the threshold above which waves are classed as ultrasound.

(Total for Question 9 is 1 mark)

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10 A medical ultrasound scan sends pulses into the body and detects echoes from tissue boundaries. A pulse reflects from a boundary 4.0 cm below the probe and the echo returns to the probe in 5.9×10^{-5} s. Calculate the speed of ultrasound in the tissue. Use the fact the pulse travelled to the boundary and back.

(Total for Question 10 is 3 marks)

11 Describe briefly how an ultrasonic flaw detector locates a crack inside a metal block, naming the role of partial reflection at a boundary between media.

(Total for Question 11 is 3 marks)

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12 Explain how ultrasound is used to produce an image of a fetus during prenatal scanning, including how echoes are used to build the image and why ultrasound is suitable for soft tissues.

(Total for Question 12 is 4 marks)

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13 A student uses an apparatus to measure the speed of sound in air. She emits a short sharp sound near a flat wall and records echo times at different known distances. She records an echo time of 0.30 s when standing 51 m from the wall. Using this data point, calculate the measured speed of sound implied by these values.

(Total for Question 13 is 3 marks)

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14 Describe one industrial use of ultrasound other than flaw detection, and give a brief explanation of how it works in that use.

(Total for Question 14 is 2 marks)

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15 State one safety advantage of ultrasound imaging compared with X-ray imaging when scanning a pregnant woman, and give a short reason.

(Total for Question 15 is 1 mark)

16 A teacher demonstrates that sound requires a medium by placing a bell inside a glass jar and extracting the air with a pump so the bell rings more quietly as the air is removed. State the variable that is being changed in this demonstration and why the sound becomes quieter as the air is removed.

(Total for Question 16 is 2 marks)

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17 A technician uses ultrasound at 25 kHz for an industrial cleaning bath. State whether this frequency is ultrasound and give its value in hertz.

(Total for Question 17 is 1 mark)

Mark scheme · IG.P7 Sound Waves and Ultrasound

Question 1

- **B1** sound waves are longitudinal
- **Answer: Longitudinal**

Question 2

- **B1** no medium in a vacuum so there are no particles to vibrate and carry the sound
- **Answer: Because a vacuum has no particles to vibrate, there is no medium to carry sound waves**

Question 3

- **B1** 20 Hz to 20000 Hz (20 kHz)
- **Answer: About 20 Hz to 20000 Hz**

Question 4

- **B1** $v = f \times \lambda$ or $v = f \times \lambda$ written correctly
- **B1** identifies symbols: v is wave speed, f is frequency, λ is wavelength
- **Answer: $v = f \times \lambda$, where v is wave speed, f is frequency and λ is wavelength**

Question 5

- **M1** quotes equation $\lambda = v / f$ or rearranges $v = f \times \lambda$ to $\lambda = v / f$
- **M1** substitutes values: $\lambda = 340 / 440$
- **A1** $\lambda = 0.773$ m cao (allow 0.77 m or 0.773... m)
- **Answer: 0.773 m (about 0.77 m)**

Question 6

- **B1** states it is within the human hearing range
- **B1** gives correct brief reason, e.g. 1000 Hz is between 20 Hz and 20000 Hz
- **Answer: Yes, 1000 Hz is within the human hearing range, because it lies between 20 Hz and 20000 Hz**

Question 7

- **M1** knows total travel time corresponds to sound going to cliff and back, so time to cliff = 2.4 / 2
- **M1** uses distance = speed x time with t = 1.2 s, so distance = 340 x 1.2
- **A1** distance = 408 m cao
- **Answer: 408 m**

Question 8

- **M1** uses $\lambda = v / f$ and substitutes v = 340 m/s and f = 50000 Hz
- **M1** performs division 340 / 50000
- **A1** $\lambda = 0.0068$ m cao (6.8×10^{-3} m, allow 0.0068 m)
- **Answer: 0.0068 m (6.8 mm)**

Question 9

- **B1** ultrasound has frequency above 20000 Hz
- **Answer: Ultrasound is sound with frequency above 20000 Hz**

Question 10

- **M1** recognises total distance = 2 x 4.0 cm = 8.0 cm = 0.080 m
- **M1** uses speed = distance / time with distance 0.080 m and time 5.9×10^{-5} s
- **A1** speed = 1360 m/s cao (allow 1350-1360 m/s or 1.36×10^{3} m/s depending on rounding)
- **Answer: About 1360 m/s (1.36×10^{3} m/s)**

Question 11

- **B1** sends ultrasound pulses into the metal using a transducer
- **B1** partial reflection occurs at boundaries where material properties change, e.g. at a crack or void, producing an echo
- **B1** time delay of the echo and known speed of ultrasound in the metal gives distance to the flaw
- **Answer: Ultrasound pulses are sent into the metal; pulses are partially reflected at a crack or boundary producing echoes; the time delay and known sound speed give the flaw distance**

Question 12

- **B1** transducer sends short ultrasound pulses into the body and receives returning echoes
- **B1** partial reflections occur at boundaries between different tissues, each echo indicates a boundary at a certain depth
- **B1** computer measures time and amplitude of many echoes from across a region and converts them into a two dimensional image
- **B1** ultrasound is suitable because it is non-ionising and is strongly reflected by tissue boundaries while penetrating soft tissue reasonably well
- **Answer: A transducer emits pulses and detects echoes from tissue boundaries; timing and strength of echoes from many directions are processed into an image; ultrasound penetrates soft tissue and is non-ionising so it is suitable for prenatal imaging**

Question 13

- **M1** recognises total distance = 2 x 51 m = 102 m and sets speed = distance / time
- **M1** computes speed = 102 / 0.30
- **A1** speed = 340 m/s cao (equals 340 m/s)
- **Answer: 340 m/s**

Question 14

- **B1** names a valid industrial use, e.g. ultrasonic cleaning or level sensing
- **B1** gives a correct brief explanation of the principle, e.g. cleaning: ultrasound in a cleaning bath produces cavitation and agitation that removes contaminants; level sensing: echoes from a liquid surface measure distance to detect level
- **Answer: Example: ultrasonic cleaning, where high frequency pulses produce cavitation bubbles that remove dirt from objects; or level sensing using echo times to measure liquid height**

Question 15

- **B1** states that ultrasound is non-ionising so it does not damage DNA like X-rays might
- **Answer: Ultrasound is non-ionising, so it does not carry the same risk of DNA damage as X-rays**

Question 16

- **B1** identifies the independent variable: amount or pressure of air in the jar
- **B1** explains that fewer particles or lower pressure means less efficient transmission of vibrations so sound intensity decreases
- **Answer: The amount/pressure of air is changed; as air is removed there are fewer particles to carry vibrations so the sound becomes quieter**

Question 17

- **B1** yes, it is ultrasound and 25 kHz = 25000 Hz
- **Answer: Yes, it is ultrasound; 25 kHz = 25000 Hz**