IB · DP · Physics

3 hours 14 questions

Structured Questions

4.2 Travelling Waves

4.2.1 Properties of Waves / 4.2.2 Transverse & Longitudinal Waves / 4.2.3 Electromagnetic Waves / 4.2.4 Sound Waves

Easy (5 questions)	/58
Medium (5 questions)	/60
Hard (4 questions)	/41
Total Marks	**/159**

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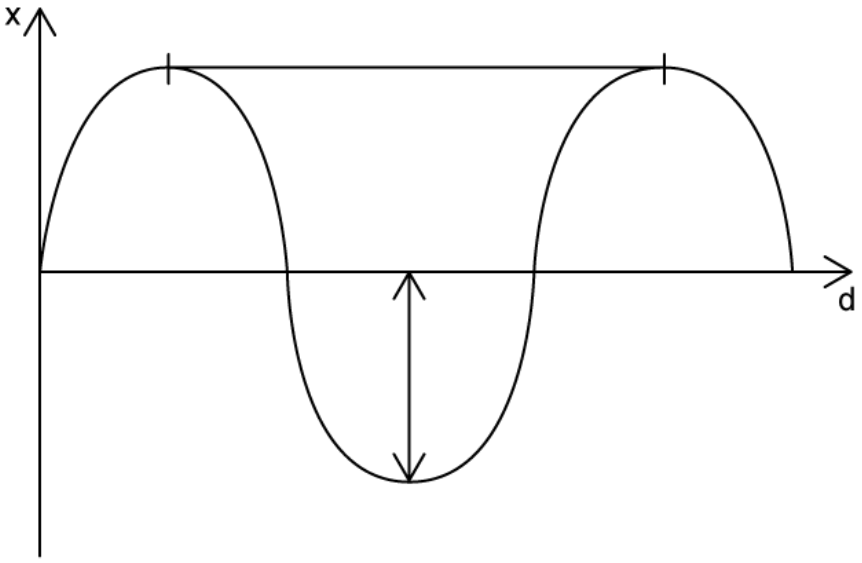
Easy Questions

1 (a) The displacement-distance graph shows a travelling wave.



Label the diagram with the correct wave features

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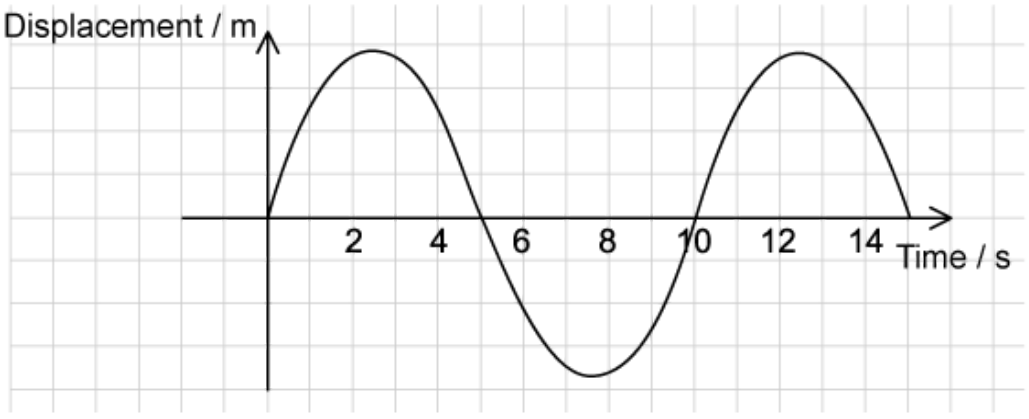
(2 marks)

(b) Match the key word to its correct definition

Period	Time taken for a point on a wave to undergo one complete oscillation
Amplitude	Number of complete oscillations per second
Frequency	Distance travelled by a wave per unit time
Wavelength	Maximum displacement of a wave from its equilibrium position
Wave speed	Distance between the same point on two consecutive waves

(5 marks)

(c) The diagram shows a displacement-time graph for an oscillating object.



Determine the time period *T* for this oscillation

(1 mark)

(d) The oscillation shown in part (c) has a wavelength λ of 5 m.

Calculate:

(i) The frequency f of the oscillation

[2]

(ii) The wave speed c

[2]

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(4 marks)

2 (a) Complete the following sentences by circling the correct words:

In a **transverse / longitudinal** wave the oscillations are perpendicular to the direction energy transfer.

In a **transverse / longitudinal** wave the oscillations are parallel to the direction energy transfer.

Transverse / Longitudinal waves do not require a medium through which to propagate.

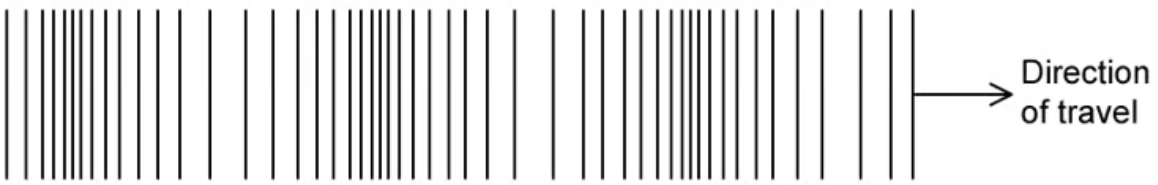
A rarefaction is an area of **high / low** pressure in **transverse / longitudinal** waves.

Radio waves and the vibrations on a guitar string are examples of **transverse / longitudinal** waves.

Sound travelling through air is an example of a **transverse / longitudinal** wave.

(6 marks)

(b) The diagram shows a longitudinal wave.



Mark on the diagram one complete wavelength and label it λ

(1 mark)

(c) The diagram shows a longitudinal wave.

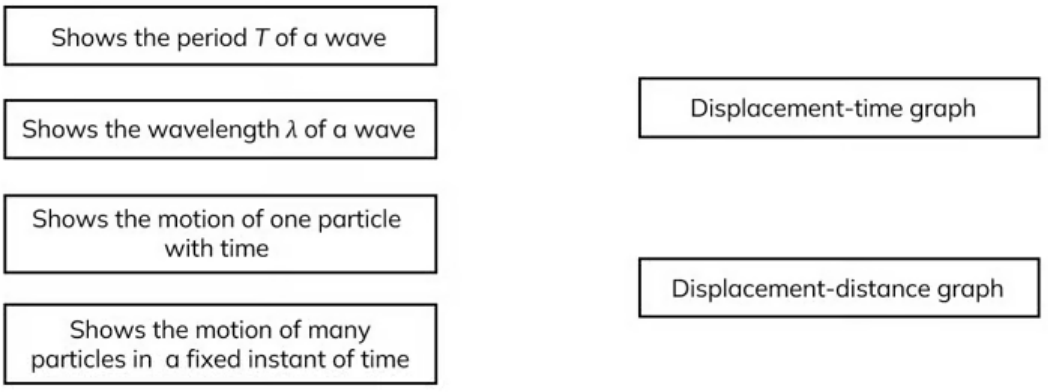
Choose suitable words and phrases to complete the sentences.

closer together	further apart	compression	rarefaction
left and right	from left to right	low	high

Label A indicates a _____. This is an area of _____ pressure where the particles are _____.
Label B indicates a _____. This is an area of _____ pressure where the particles are _____.
The particles oscillate _____. The direction of motion and energy transfer is _____.

(6 marks)

(d) Draw a line for each statement to identify whether it refers to a displacement-distance graph or a displacement-time graph.



(4 marks)

3 (a) State the speed of microwaves in a vacuum.

.....

(1 mark)

(b) Calculate the frequency f of an infrared wave with a wavelength $\lambda = 2.5 \times 10^{-6}$ m s^{-1}.

.....

.....

(2 marks)

(c) Order the electromagnetic waves by wavelength λ. Write a number from 1 to 7 in the column with 1 being the longest wavelength and 7 being the shortest wavelength.

Electromagnetic Wave	Order of wavelength λ
Visible light	
X-rays	
Infrared	
Gamma rays	7
Radio waves	
Ultraviolet	
Microwaves	

.....

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.....

(3 marks)

(d) State the longest and shortest wavelengths λ for visible light.

.....

.....

(2 marks)

4 (a) Define a longitudinal wave.

.....

(1 mark)

(b) Define a transverse wave.

.....

(1 mark)

(c) Give three examples of transverse waves.

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.....

.....

(3 marks)

(d) State an electromagnetic wave with a frequency higher than visible light.

.....

(1 mark)

5 (a) State the lowest and highest frequencies that are detectable to the human ear.

(2 marks)

(b) Complete the following sentences by adding the correct words into the gaps:

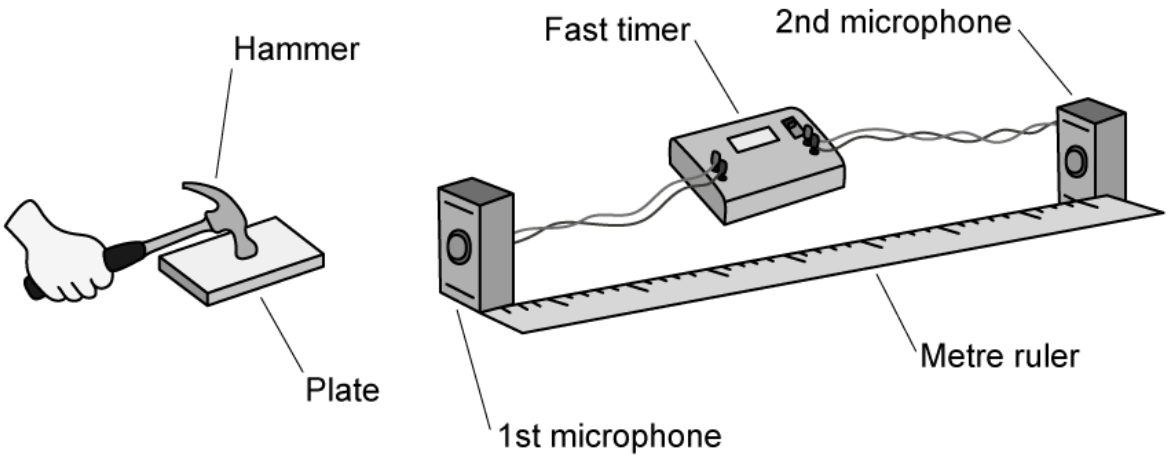
These words can be used once, more than once, or not at all					
frequency	slow	fast	small		
high	volume	large	low	amplitude	pitch

The frequency of a sound wave is related to its _____. Sounds with a _____ frequency have a high _____. Sounds with a _____ frequency have a low _____.

The amplitude of a sound wave is related to its _____. Sounds with a _____ amplitude have a high _____. Sounds with a _____ amplitude have a low _____.

(6 marks)

(c) A fast timer was used to measure the time taken for a sound to travel between two microphones.

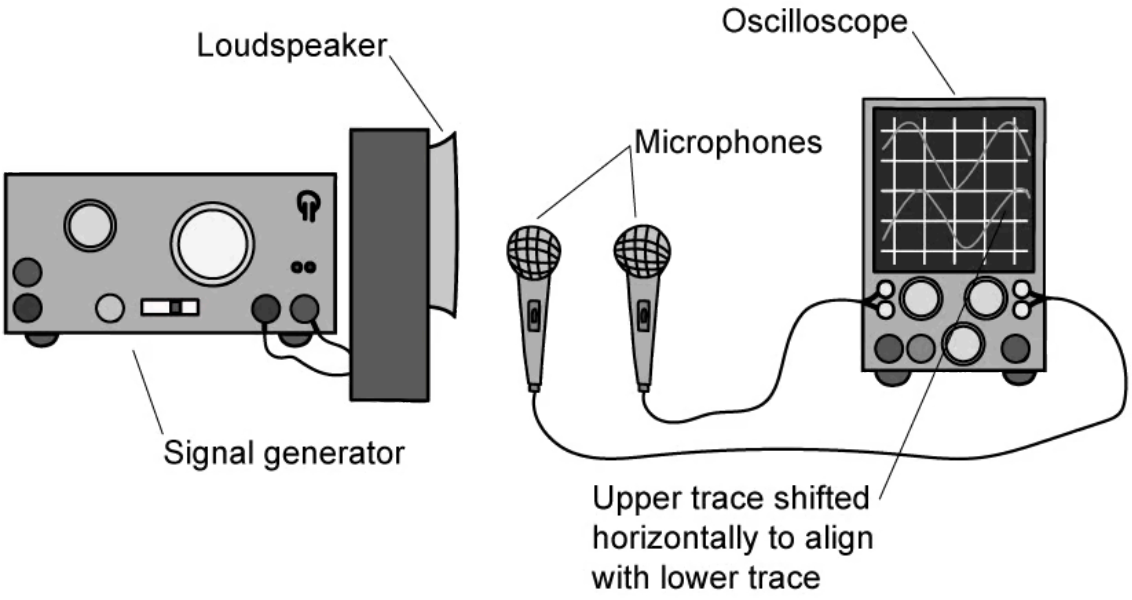


The microphones were placed 80 cm apart. The mean time interval was 2.5 ms.

Calculate the speed of the sound

(4 marks)

(d) A signal generator was set to produce a sound wave at 1 kHz. Two microphones detect the sound and show the traces on a double beam oscilloscope.



The second microphone was moved away from the first microphone until the oscilloscope traces aligned. The distance between the microphones at this point showed that the wavelength of the sound wave was 3.4 cm.

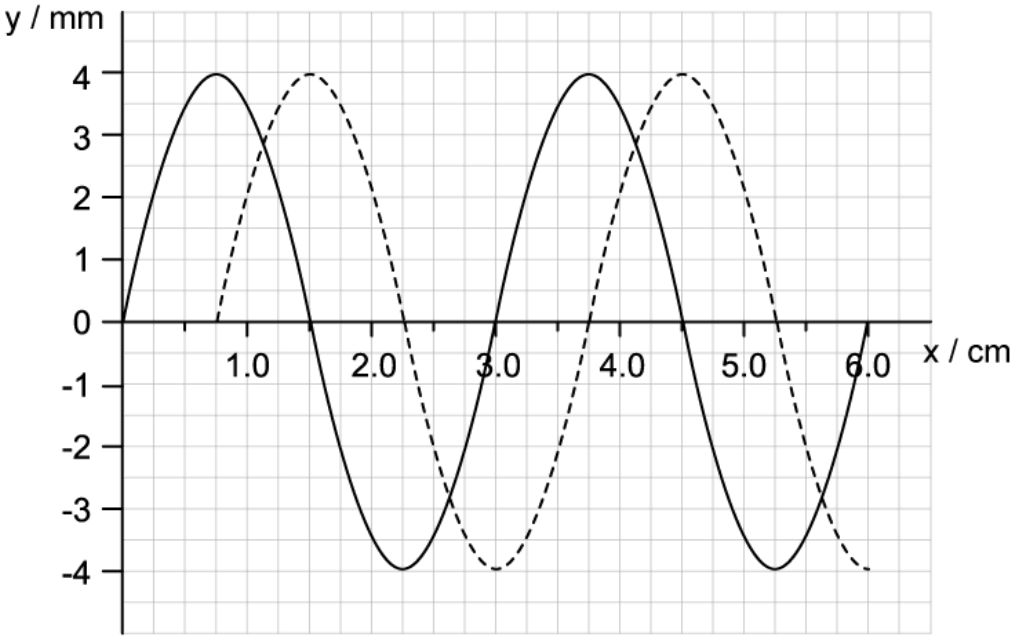
Calculate the speed of the sound

(3 marks)

Medium Questions

1 (a) A wave on the surface of a ripple tank moves from the source at the rear of the tank to the front. The graph shows the variation with distance *x* of the displacement *y* of the surface of the water.

The solid line shows displacement at t = 0 and the dashed line shows the displacement at t = 0.154 s.



Describe the difference between transverse and longitudinal waves.

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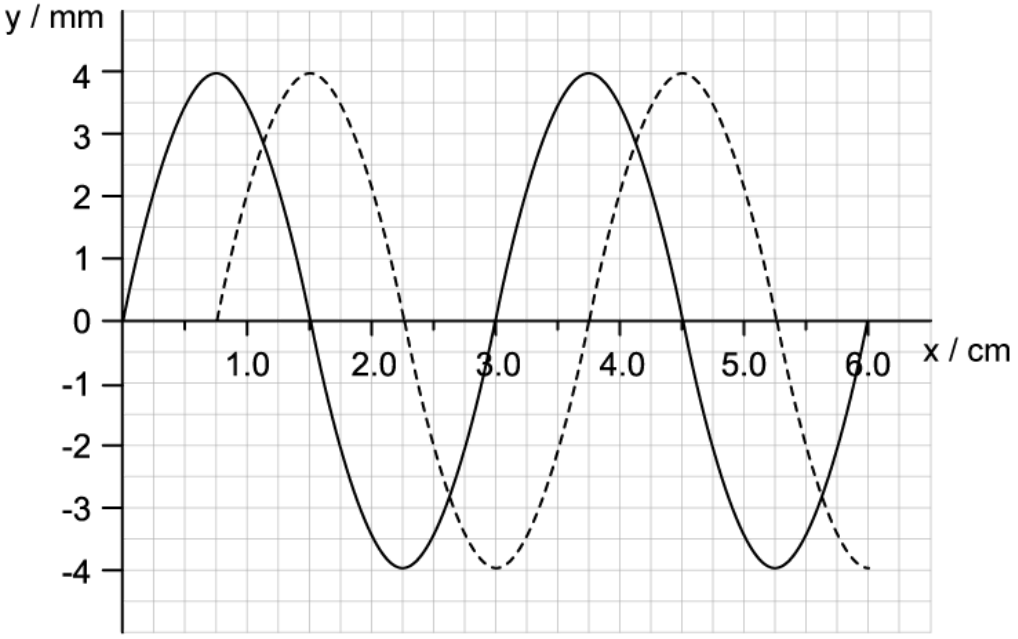
(2 marks)

(b) Calculate for the wave on the ripple tank



(i) the speed

[2]

(ii) the frequency

[2]

(4 marks)

(c) The graph shows the motion of the water waves at a point where displacement ≤ 6.0 cm.

Describe the appearance of the wave after being displaced by twice this distance.

(3 marks)

(d) The initial amplitude of the ripples is 0.38 cm.

Sketch a graph of displacement against time to show the motion of the surface of the water for the first 3.0 s.

(3 marks)

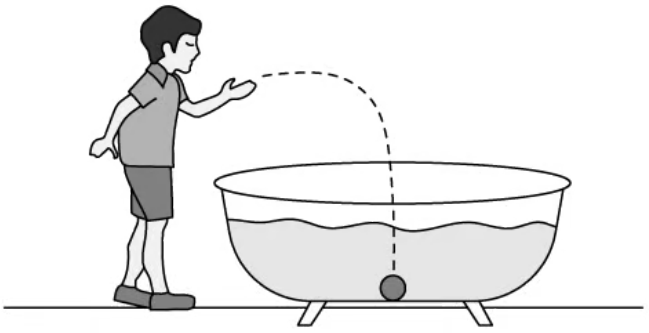
2 (a) A sound wave in air has a speed of 330 m s^{-1}. The distance between a rarefaction and compression is 1.3 m for this particular soundwave.

Calculate the time period of the sound wave.

(3 marks)

(b) A stone is dropped into a metal bath filled with water, and the sound of it landing is heard by a person in the room.

The sound waves generated by the impact of the stone travels to the person at different speeds through the metal of the bath, the water and the air.



The metal of the bath is 0.5 cm thick, the water is 23 cm deep, and the ears of the person are 160 cm above the base of the bath.

You may use the following values:

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

Speed of sound in metal = 3000 m s^{-1}

Speed of sound in water = 1500 m s^{-1}

(i) Explain why the person only hears the sound once, rather than twice

[1]

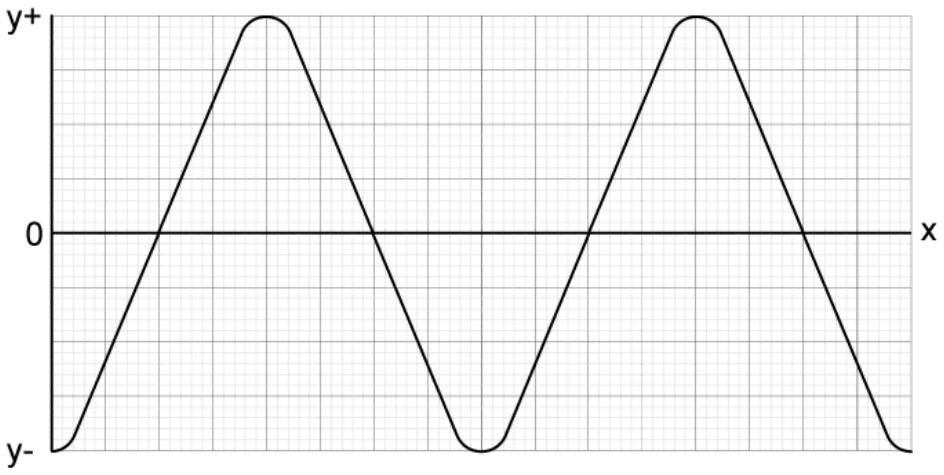
(ii) Calculate the time difference between the sound arriving at the person's ear from the inside (through the water) and the outside (through the metal) of the bath

[3]

(4 marks)

(c) The graph shows the displacement *y* of the particles in air due to the progression of the sound wave *x* from the source to the ear.

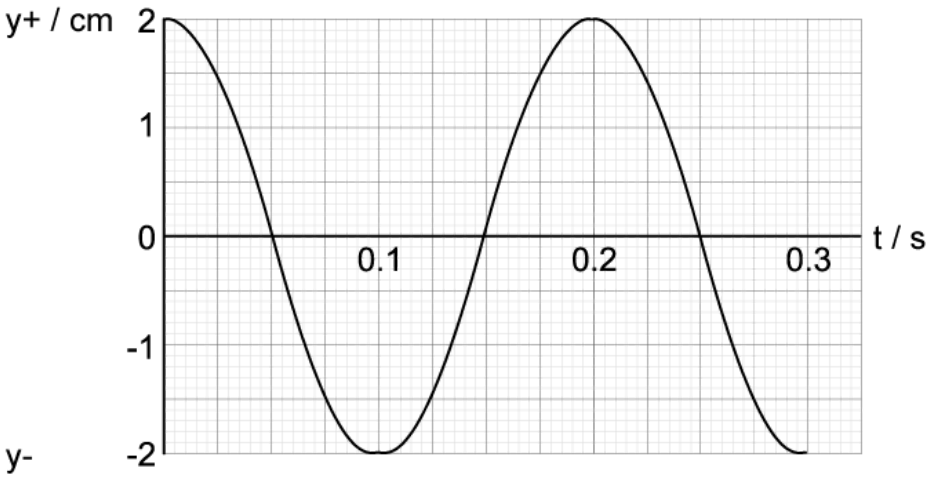
Positive displacement indicates movement towards the person and negative displacement is away from them.



Annotate on a sketch of the graph the position of at least two compressions and two rarefactions.

(2 marks)

(d) The graph shows the variation with time *t* of the displacement *y* of a particle in the metal of the bath.



For the longitudinal wave:

(i) Calculate the frequency of the wave

[1]

(ii) Determine the speed it is moving at when t = 0.15 s

[2]

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.....

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(3 marks)

3 (a) (i) Outline what is meant by an electromagnetic (EM) wave.

[2]

(ii) Compare EM waves to ultrasound waves.

[1]

(3 marks)

(b) When doctors want to use medical imaging to observe a foetus in the uterus, ultrasound is used rather than x-rays.

Ultrasound produces images which are less detailed.

(i) Describe why ultrasound is chosen over x-rays despite the lack of resolution of the images produced.

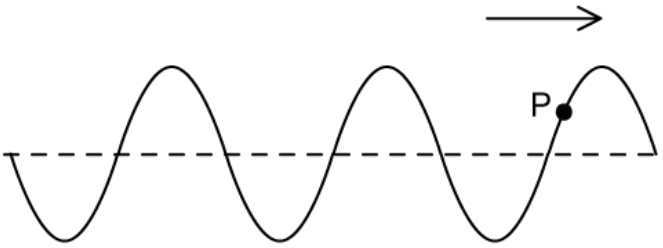
[2]

(ii) Explain why ultrasound images have lower resolution.

[2]

(4 marks)

(c) Electromagnetic waves can be modelled using a stretched string with a wave passing along it. In the diagram, a wave is travelling to the right. The equilibrium position of the waveform is marked with a dashed line and a point, P is indicated.



The frequency of the wave is 0.5 Hz.

Annotate the diagram as instructed below.

(i) Starting at point P, identify the wavelength of the wave.

[1]

(ii) Indicate the motion of point P from the instant until 0.5 s later.

[2]

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(3 marks)

(d) The string is being oscillated at one end to cause a frequency *f* of 0.5 Hz and wavelength, λ of 30 cm.

(i) Determine the speed of the wave

[1]

(ii) Deduce the change which must be made to reduce the wavelength to 20 cm. Assume that the length of the string is constant

[2]

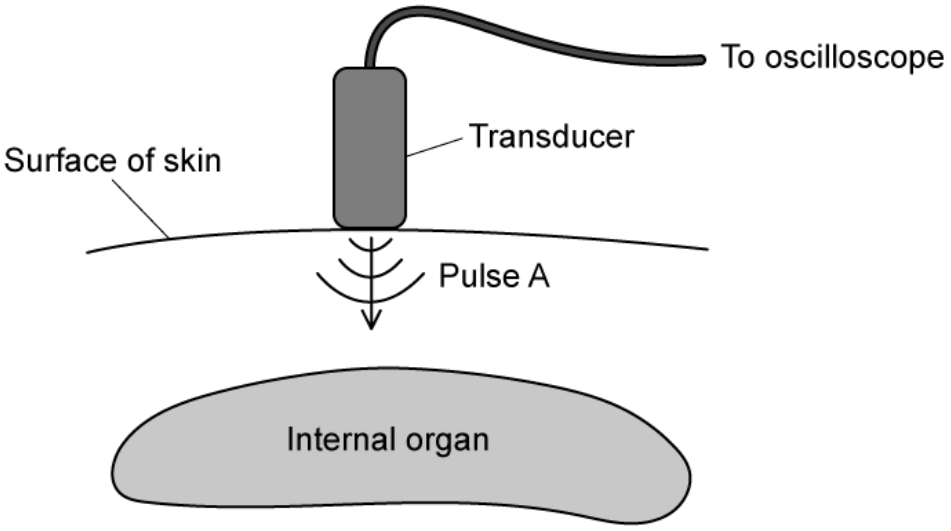
.....

.....

(3 marks)

4 (a) Ultrasound scanners are used in hospitals to establish the depth of internal organs under the skin. A pulse of ultrasound is emitted from a transducer, which also detects reflections of the pulse from internal organs.

Reflected pulses are displayed on the screen of an oscilloscope.



Explain how the energy is transferred in the ultrasound.

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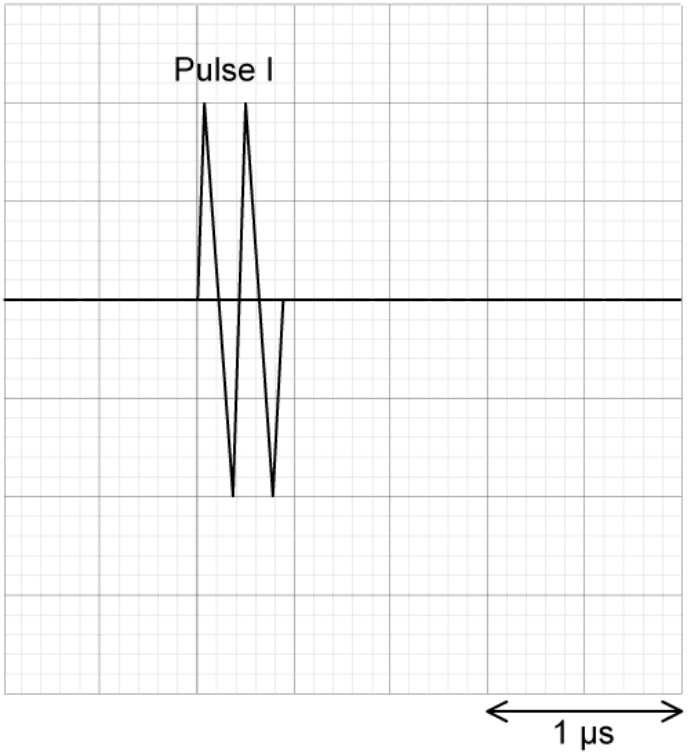
(2 marks)

(b) The display shows the appearance of the first pulse, Pulse I on an oscilloscope.



Determine the frequency of the pulse of ultrasound.

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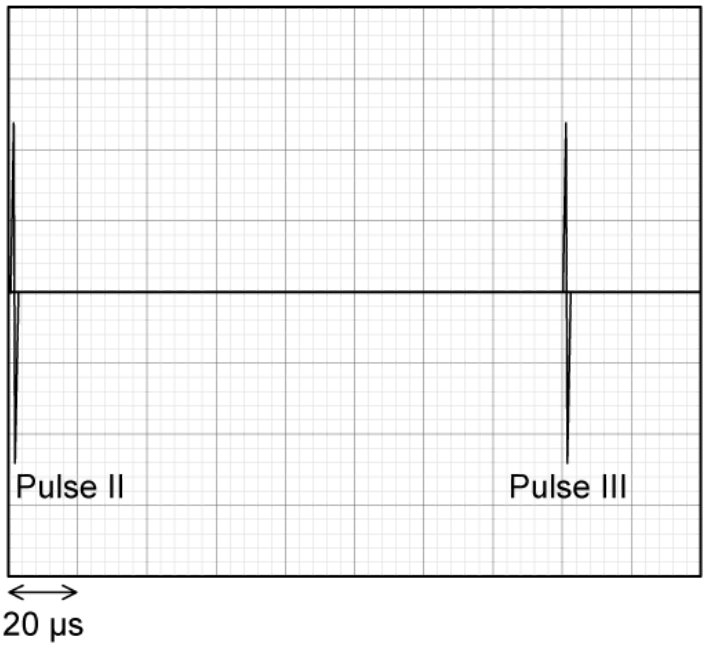
(3 marks)

(c) The scanner emits ultrasound pulses at regular time intervals. A display of two successive pulses, II and III would show a separation between them.

The reflection of pulse II must be detected before pulse III is emitted. This means that the equipment has a maximum depth within the body which it can clearly create an image from.



Calculate this maximum depth.

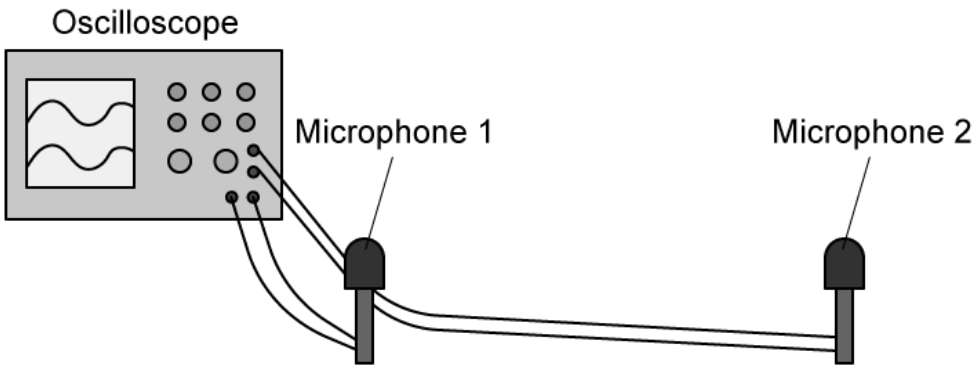
- Speed of ultrasound in body tissue = 1540 m s^{-1}
- The time-base is set to 20 μs div^{-1}.

(3 marks)

(d) Calculate the wavelength of an electromagnetic wave with a frequency equal to that of the ultrasound wave.

(2 marks)

5 (a) A common investigation to determine the speed of sound uses two microphones connected to a double-beam oscilloscope.



Outline how this equipment can be used to find the speed of sound.

(i) List any additional equipment required

[2]

(ii) Briefly outline the method

[2]

(iii) Indicate the measurements to be taken

[1]

You may choose to draw a diagram as part of your answer.

(5 marks)

(b) Sketch a graph to show the traces which would be observed on the double-beam oscilloscope at a point where:

(i) No result would be measured and recorded

[1]

(ii) A result would be measured and recorded

[1]

.....

.....

(2 marks)

(c) The teacher planning the investigation to be set up on lab benches where the furthest distance that could be measured is 2.0 m.

Suggest a sensible range of frequencies for the signal generator.

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(3 marks)

(d) The students consider how their measurements would be different if they could conduct the experiment under different conditions.

Without further calculation, explain what changes would be made to the frequency range used for an experiment conducted

(i) underwater

(ii) in a gas tank filled with Helium

.....

(3 marks)

Hard Questions

1 (a) Waves can be described as either transverse or longitudinal.

Illustrate and explain the terms transverse and longitudinal, giving examples of each.

(6 marks)

(b) A satellite passing Neptune communicates with Earth using a microwave transmitter with an output power of 24.0 W and wavelength 78 900 μm.

The satellite's controller is located on Earth, at a distance of 4.40×10^{12} m when the signal is transmitted.

For this communication

(i) Calculate the time taken for the signal to be detected by the controller.

[1]

(ii) Calculate the energy of a microwave photon.

[2]

(3 marks)

(c) The controller dish aerial has an effective area of 258 m^2.

For the communication from part (b)

(i) Determine the power received by the controller dish aerial. You may assume that the power transmitted by the satellite radiates uniformly in all directions.

[2]

(ii) The actual power received by the controller dish aerial is 1.4×10^{-15} W. Suggest why this is different to the calculated power received.

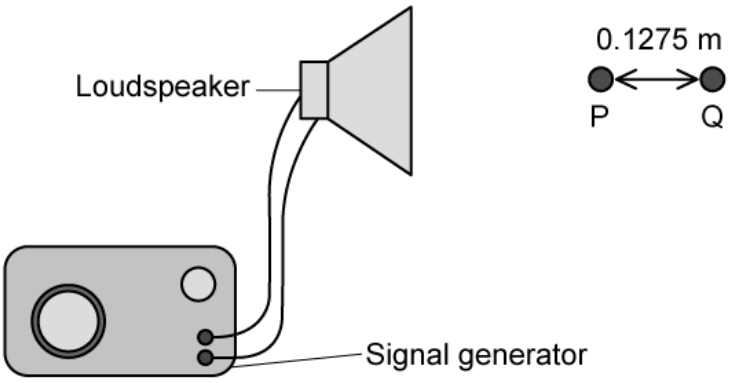
[2]

(iii) Calculate the rate at which microwave photons arrive at the controller dish aerial.

[2]

(6 marks)

2 (a) A signal generator is connected to a loudspeaker and produces an output signal with 6.70×10^2 oscillations per second.



Determine the wavelength, λ, of the sound wave.

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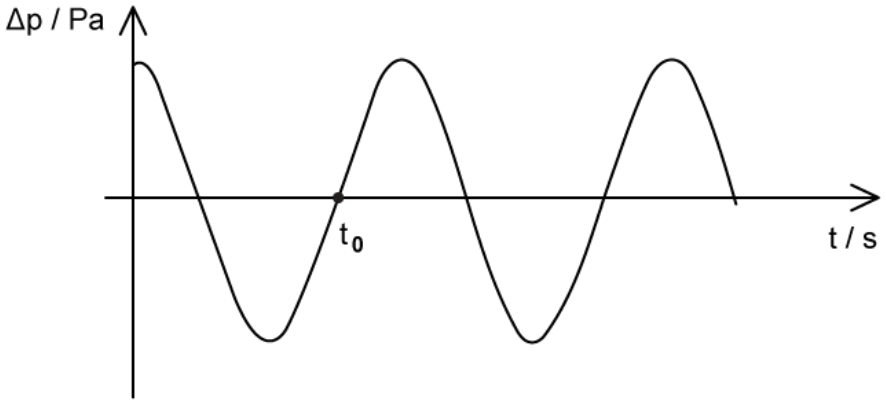
(2 marks)

(b) The graph shows the change in pressure, Δp, at point P as a function of time, t, as the sound wave passes.



Deduce the value of t_0.

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(1 mark)

(c) State the phase of the oscillation at point Q relative to point P and justify your answer.

.....

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(2 marks)

(d) Suggest and explain one **other** feature of the Δp-t graph that would be different at point Q in relation to point P.

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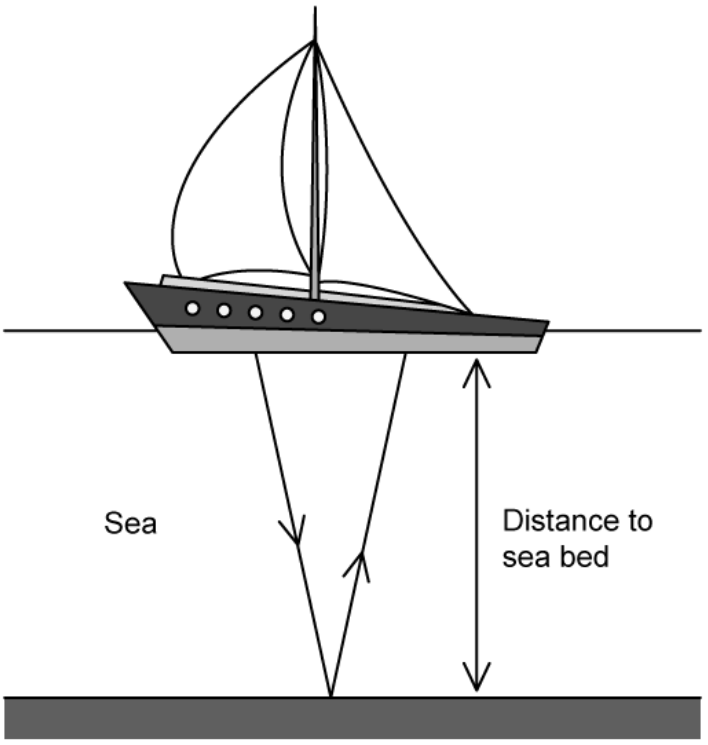
(2 marks)

3 (a) Ultrasound is used to measure the depth of oceans, seas and lakes.

The diagram shows a pulse of ultrasound being emitted from the boat, travelling down to the sea bed and being reflected back to the boat.



Outline the term ultrasound.

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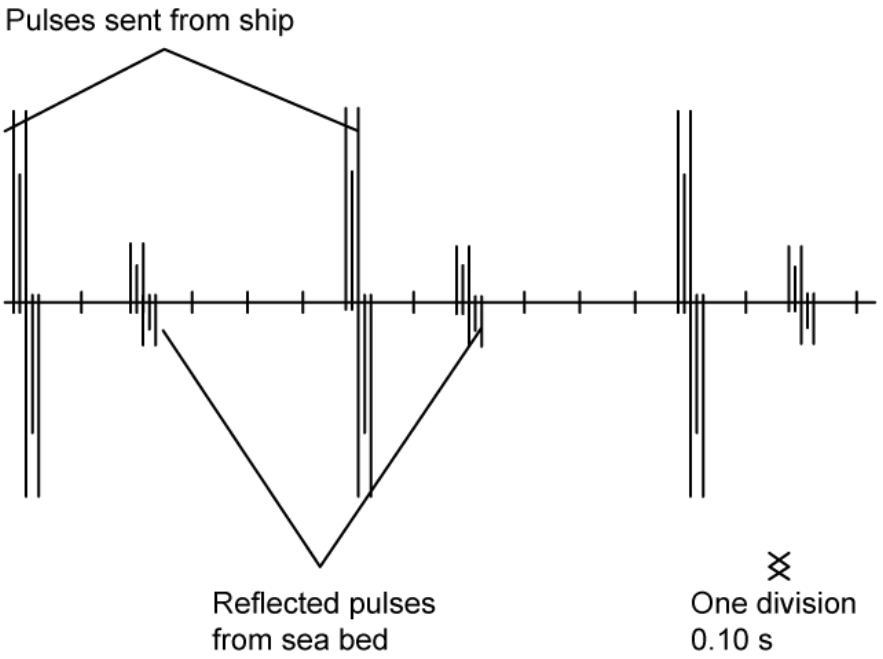
(2 marks)

(b) A cathode-ray oscilloscope (C.R.O.) is used to trace the ultrasound pulses sent from the boat and the reflected pulses returning to the boat.



The ultrasound travels through water at 1 452 m s^{-1}, and the wavelength of the pulse is 0.023 m.

For the ultrasound pulses:

(i) Calculate the frequency

[1]

(ii) Calculate the distance to the sea bed

[2]

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(3 marks)

(c) The boat moves out to an area where the sea is deeper.

(i) State and explain two changes that would occur on the cathode-ray oscilloscope trace. You may include diagrams in your answer.

[4]

(ii) When the sea is over 450 m deep, the pulses must be transmitted less frequently. Explain why this is the case.

[4]

(8 marks)

4 (a) A boulder falls into a lake and ripples propagate radially outwards. Two boats on the surface of the water are in line with the source and perform the simple harmonic motion, bobbing up and down as the ripples pass by. The boats are separated by a distance of 45 m.

Two observations were recorded; the first ripple took 3.8 s to travel between the boats; the boats are completely out of phase.

Calculate the speed of the water wave.

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(2 marks)

(b) Explain why the amplitude of the wave will decrease with increasing distance from the source.

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(4 marks)