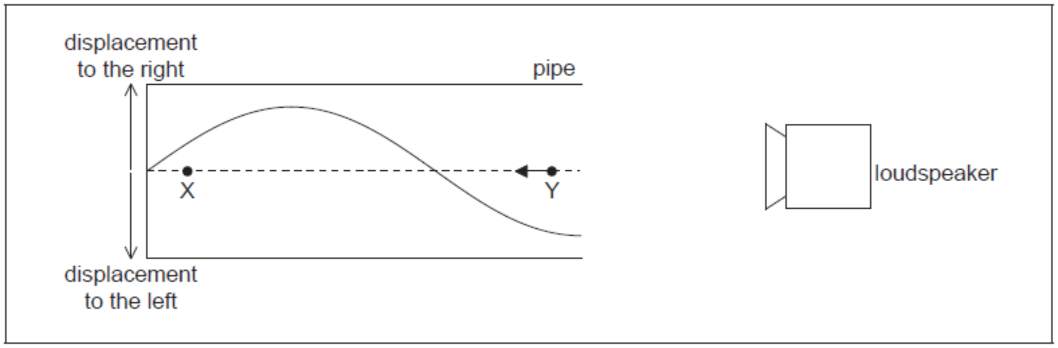
Ch4Refraction *[58 marks]*

A loudspeaker emits sound towards the open end of a pipe. The other end is closed. A standing wave is formed in the pipe. The diagram represents the displacement of molecules of air in the pipe at an instant of time.



1a. Outline how the standing wave is formed. *[1 mark]*

X and Y represent the equilibrium positions of two air molecules in the pipe. The arrow represents the velocity of the molecule at Y.

1b. Draw an arrow on the diagram to represent the direction of motion of the molecule at X. *[1 mark]*

1c. Label a position N that is a node of the standing wave. *[1 mark]*

1d. The speed of sound is 340 m s^{-1} and the length of the pipe is 0.30 m. Calculate, in Hz, the frequency of the sound. *[2 marks]*

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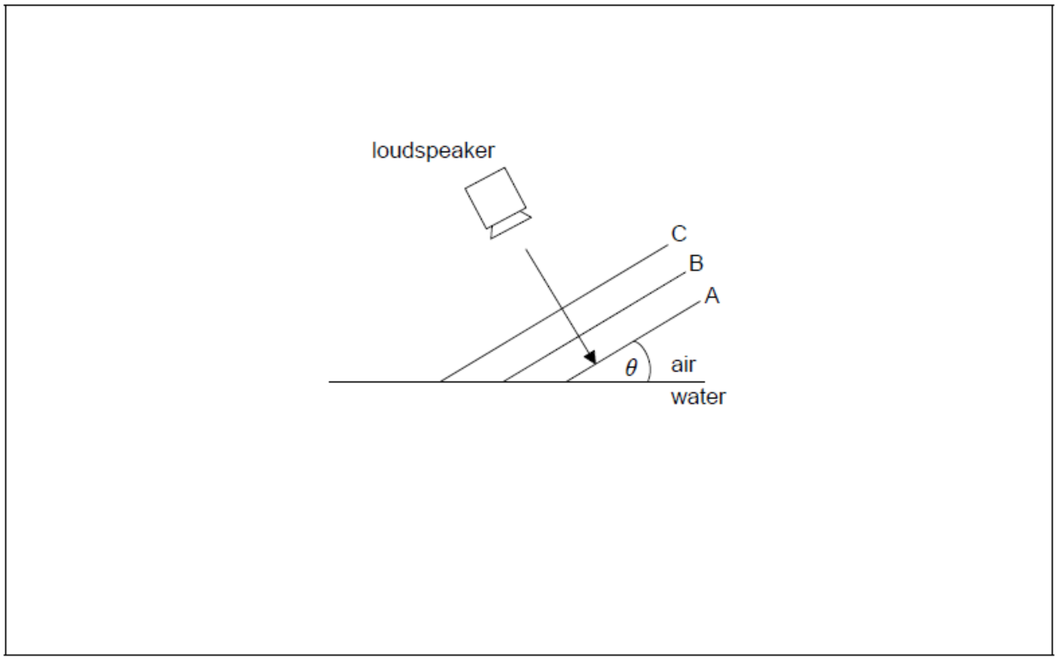
The loudspeaker in (a) now emits sound towards an air–water boundary. A, B and C are parallel wavefronts emitted by the loudspeaker. The parts of wavefronts A and B in water are not shown. Wavefront C has not yet entered the water.



1e. The speed of sound in air is 340 m s^{-1} and in water it is 1500 m s^{-1}. *[2 marks]*

The wavefronts make an angle θ with the surface of the water. Determine the maximum angle, θ_{max}, at which the sound can enter water. Give your answer to the correct number of significant figures.

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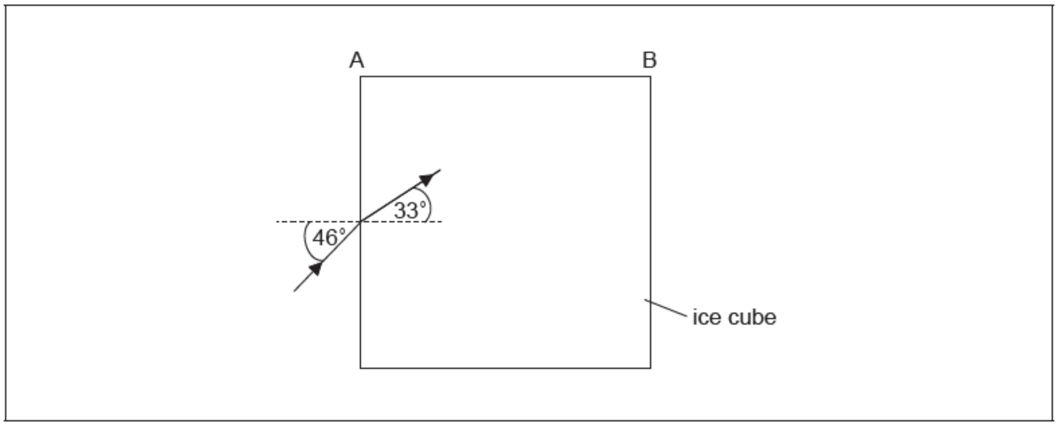
1f. Draw lines on the diagram to complete wavefronts A and B in water for $\theta < \theta_{max}$. *[2 marks]*

A large cube is formed from ice. A light ray is incident from a vacuum at an angle of 46˚ to the normal on one surface of the cube. The light ray is parallel to the plane of one of the sides of the cube. The angle of refraction inside the cube is 33˚.



2a. Calculate the speed of light inside the ice cube. *[2 marks]*

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2b. Show that no light emerges from side AB. *[3 marks]*

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2c. Sketch, on the diagram, the subsequent path of the light ray. *[2 marks]*

Each side of the ice cube is 0.75 m in length. The initial temperature of the ice cube is –20 °C.

2d. Determine the energy required to melt all of the ice from –20 °C to water at a temperature of 0 °C. *[4 marks]*

Specific latent heat of fusion of ice = 330 kJ kg^{-1}
Specific heat capacity of ice = 2.1 kJ kg^{-1} k^{-1}
Density of ice = 920 kg m^{-3}

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2e. Outline the difference between the molecular structure of a solid and a liquid. *[1 mark]*

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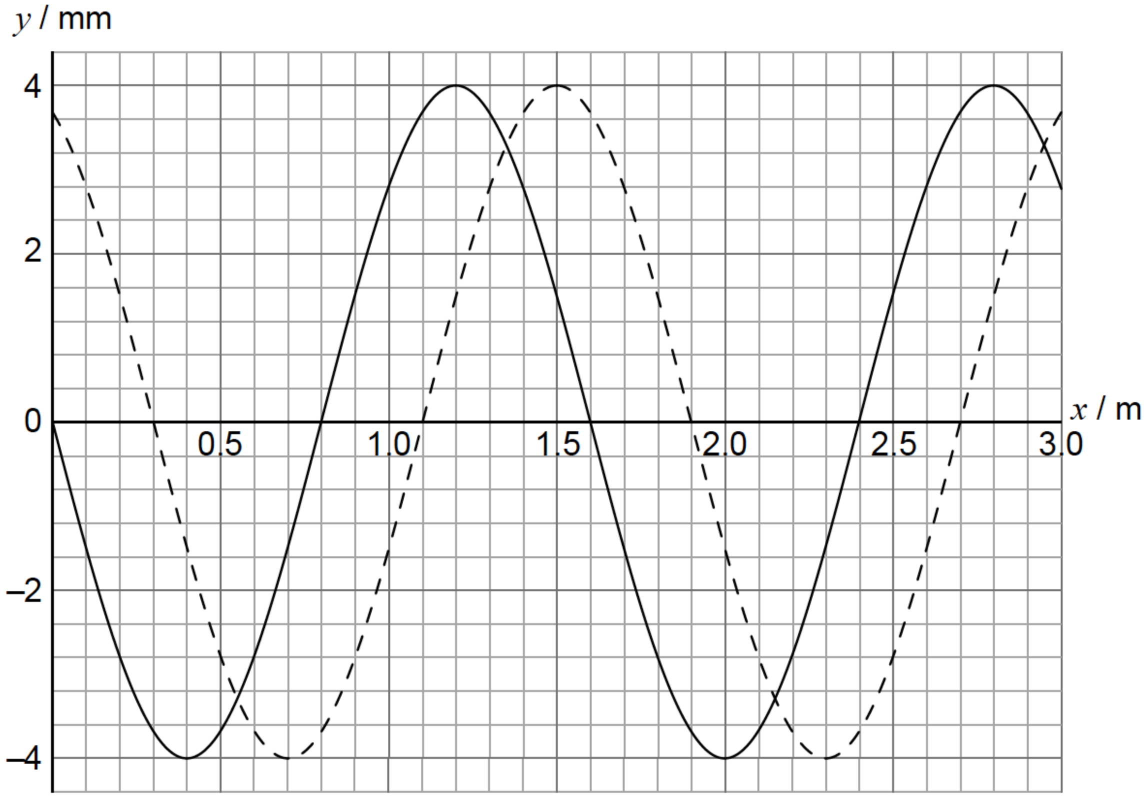
A longitudinal wave is travelling in a medium from left to right. The graph shows the variation with distance x of the displacement y of the particles in the medium. The solid line and the dotted line show the displacement at t=0 and t=0.882 ms, respectively.



The period of the wave is greater than 0.882 ms. A displacement to the right of the equilibrium position is positive.

3a. State what is meant by a longitudinal travelling wave. *[1 mark]*

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3b. Calculate, for this wave, *[4 marks]*

(i) the speed.

(ii) the frequency.

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3c. The equilibrium position of a particle in the medium is at *x*=0.80 m. For this particle at *t*=0, state and explain *[4 marks]*

(i) the direction of motion.

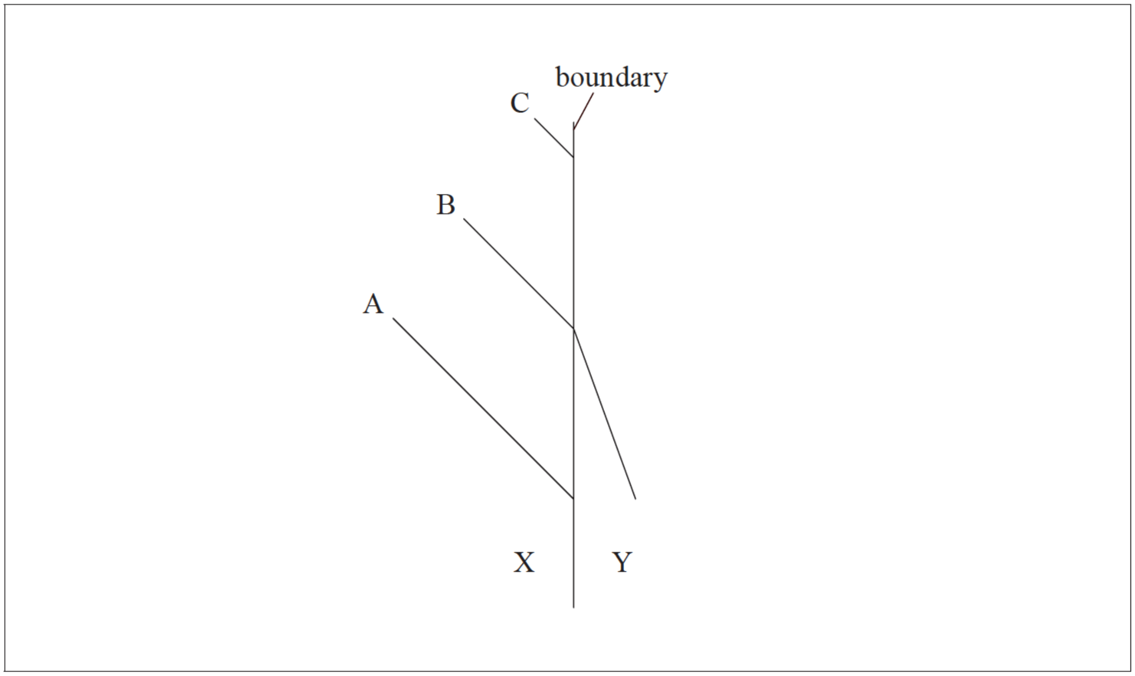
(ii) whether the particle is at the centre of a compression or a rarefaction.

This question is in **two** parts. **Part 1** is about wave motion. **Part 2** is about the melting of the Pobeda ice island.

Part 1 Wave motion

4a. State what is meant by the terms ray and wavefront and state the relationship between them. *[3 marks]*

4b. The diagram shows three wavefronts, A, B and C, of a wave at a particular instant in time incident on a boundary between media X and Y. Wavefront B is also shown in medium Y. *[4 marks]*



(i) Draw a line to show wavefront C in medium Y.

(ii) The refractive index of X is n_X and the refractive index of Y is n_Y. By making appropriate measurements, calculate $\frac{n_X}{n_Y}$.

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4c. Describe the difference between transverse waves and longitudinal waves. *[2 marks]*

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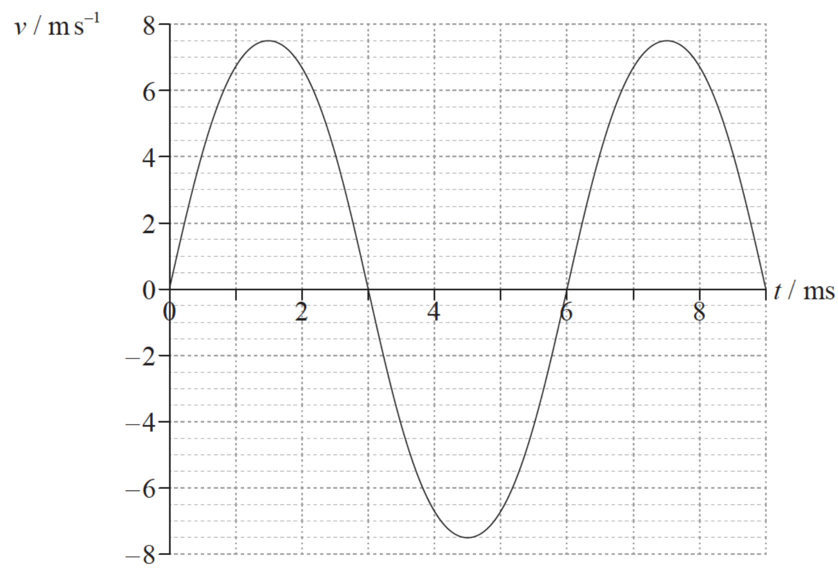
4d. The graph below shows the variation of the velocity *v* with time *t* for one oscillating particle of a medium. *[3 marks]*



(i) Calculate the frequency of oscillation of the particle.

(ii) Identify on the graph, with the letter M, a time at which the displacement of the particle is a maximum.

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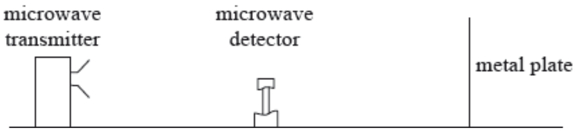
This question is in **two** parts. **Part 1** is about a lightning discharge. **Part 2** is about microwave radiation.

Part 2 Microwave radiation

A microwave transmitter emits radiation of a single wavelength towards a metal plate along a line normal to the plate. The radiation is reflected back towards the transmitter.



A microwave detector is moved along a line normal to the microwave transmitter and the metal plate. The detector records a sequence of equally spaced maxima and minima of intensity.

5a. Explain how these maxima and minima are formed. *[4 marks]*

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The microwave detector is moved through 130 mm from one point of minimum intensity to another point of minimum intensity. On the way it passes through nine points of maximum intensity. Calculate the

5b. (i) wavelength of the microwaves. *[4 marks]*

(ii) frequency of the microwaves.

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5c. Describe and explain how it could be demonstrated that the microwaves are polarized. *[3 marks]*

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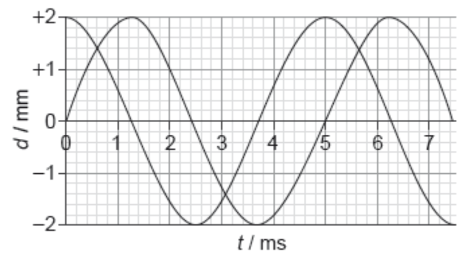
6. Two travelling waves are moving through a medium. The diagram shows, for a point in the medium, the variation with time *t* of the displacement *d* of each of the waves. *[1 mark]*



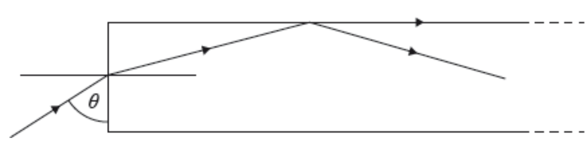
For the instant when *t* = 2.0 ms, what is the phase difference between the waves and what is the resultant displacement of the waves?

	Phase difference	Resultant displacement / mm
A.	45°	−0.6
B.	90°	2.6
C.	45°	2.6
D.	90°	−0.6

7. What are the changes in the speed and in the wavelength of monochromatic light when the light passes from water to air? *[1 mark]*

	Change in speed	Change in wavelength
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

8. A ray of light passes from the air into a long glass plate of refractive index *n* at an angle θ to the edge of the plate. *[1 mark]*

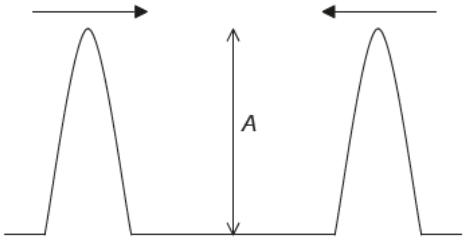


The ray is incident on the internal surface of the glass plate and the refracted ray travels along the external surface of the plate.

What change to *n* and what change to θ will cause the ray to travel entirely within the plate after incidence?

	Change to *n*	Change to θ
A.	increase	increase
B.	increase	decrease
C.	decrease	increase
D.	decrease	decrease

9. Two wave pulses, each of amplitude *A*, approach each other. They then superpose before continuing in their original directions. What is the total amplitude during superposition and the amplitudes of the individual pulses after superposition? *[1 mark]*



	Total amplitude during superposition	Individual amplitudes after superposition
A.	*A*	less than *A*
B.	*A*	*A*
C.	2*A*	less than *A*
D.	2*A*	*A*

10. The refractive index for light travelling from medium X to medium Y is $\frac{4}{3}$. The refractive index for light travelling from medium Y to medium Z is $\frac{3}{5}$. What is the refractive index for light travelling from medium X to medium Z? *[1 mark]*

A. $\frac{4}{5}$

B. $\frac{15}{12}$

C. $\frac{5}{4}$

D. $\frac{29}{15}$