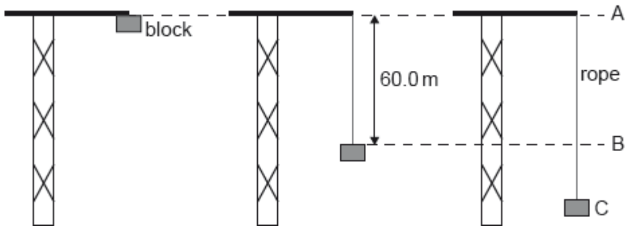
SHMP2 *[93 marks]*

An elastic climbing rope is tested by fixing one end of the rope to the top of a crane. The other end of the rope is connected to a block which is initially at position A. The block is released from rest. The mass of the rope is negligible.



The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

1a. At position B the rope starts to extend. Calculate the speed of the block at position B. *[2 marks]*

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At position C the speed of the block reaches zero. The time taken for the block to fall between B and C is 0.759 s. The mass of the block is 80.0 kg.

1b. Determine the magnitude of the average resultant force acting on the block between B and C. *[2 marks]*

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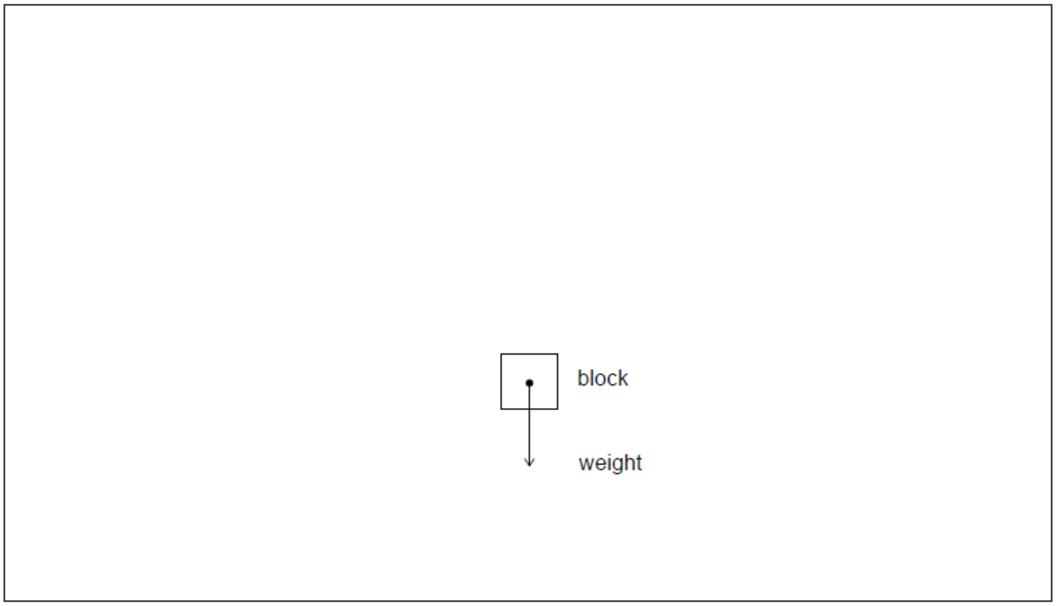
1c. Sketch on the diagram the average resultant force acting on the block between B and C. The arrow on the diagram represents the weight of the block. *[2 marks]*



1d. Calculate the magnitude of the average force exerted by the rope on the block between B and C. *[2 marks]*

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For the rope and block, describe the energy changes that take place

1e. between A and B. *[1 mark]*

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1f. between B and C. *[1 mark]*

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1g. The length reached by the rope at C is 77.4 m. Suggest how energy considerations could be used to determine the elastic constant of the rope. *[2 marks]*

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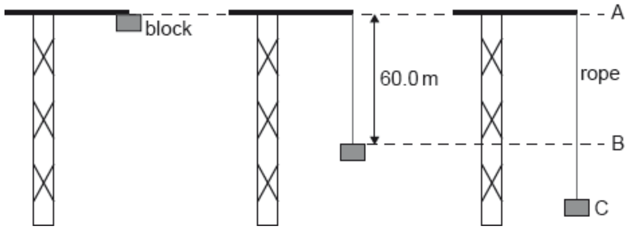
An elastic climbing rope is tested by fixing one end of the rope to the top of a crane. The other end of the rope is connected to a block which is initially at position A. The block is released from rest. The mass of the rope is negligible.



The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

In another test, the block hangs in equilibrium at the end of the same elastic rope. The elastic constant of the rope is 400 Nm^{-1}. The block is pulled 3.50 m vertically below the equilibrium position and is then released from rest.

1h. Calculate the time taken for the block to return to the equilibrium position for the first time. *[2 marks]*

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1i. Calculate the speed of the block as it passes the equilibrium position. *[2 marks]*

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A student is investigating a method to measure the mass of a wooden block by timing the period of its oscillations on a spring.

2a. Describe the conditions required for an object to perform simple harmonic motion (SHM). *[2 marks]*

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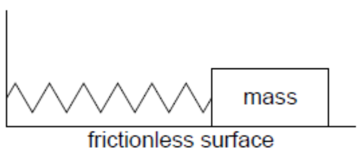
A 0.52 kg mass performs simple harmonic motion with a period of 0.86 s when attached to the spring. A wooden block attached to the same spring oscillates with a period of 0.74 s.



2b. Calculate the mass of the wooden block. *[2 marks]*

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2c. In carrying out the experiment the student displaced the block horizontally by 4.8 cm from the equilibrium position. Determine the total energy in the oscillation of the wooden block. *[3 marks]*

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2d. A second identical spring is placed in parallel and the experiment in (b) is repeated. Suggest how this change affects the fractional uncertainty in the mass of the block. *[3 marks]*

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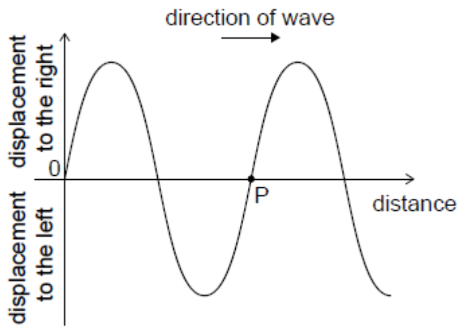
With the block stationary a longitudinal wave is made to travel through the original spring from left to right. The diagram shows the variation with distance x of the displacement y of the coils of the spring at an instant of time.



A point on the graph has been labelled that represents a point P on the spring.

2e. State the direction of motion of P on the spring. *[1 mark]*

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2f. Explain whether P is at the centre of a compression or the centre of a rarefaction. *[2 marks]*

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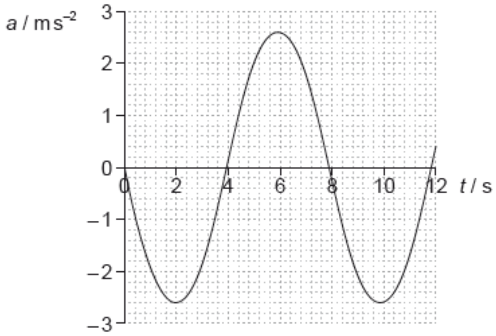
This question is about simple harmonic motion (SHM).

The graph shows the variation with time t of the acceleration a of an object X undergoing simple harmonic motion (SHM).



3a. Define *simple harmonic motion (SHM)*. *[2 marks]*

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3b. X has a mass of 0.28 kg. Calculate the maximum force acting on X. *[1 mark]*

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3c. Determine the maximum displacement of X. Give your answer to an appropriate number of significant figures. *[4 marks]*

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3d. A second object Y oscillates with the same frequency as X but with a phase difference of $\frac{\pi}{4}$. Sketch, using the graph opposite, how the acceleration of object Y varies with t. *[2 marks]*

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]*

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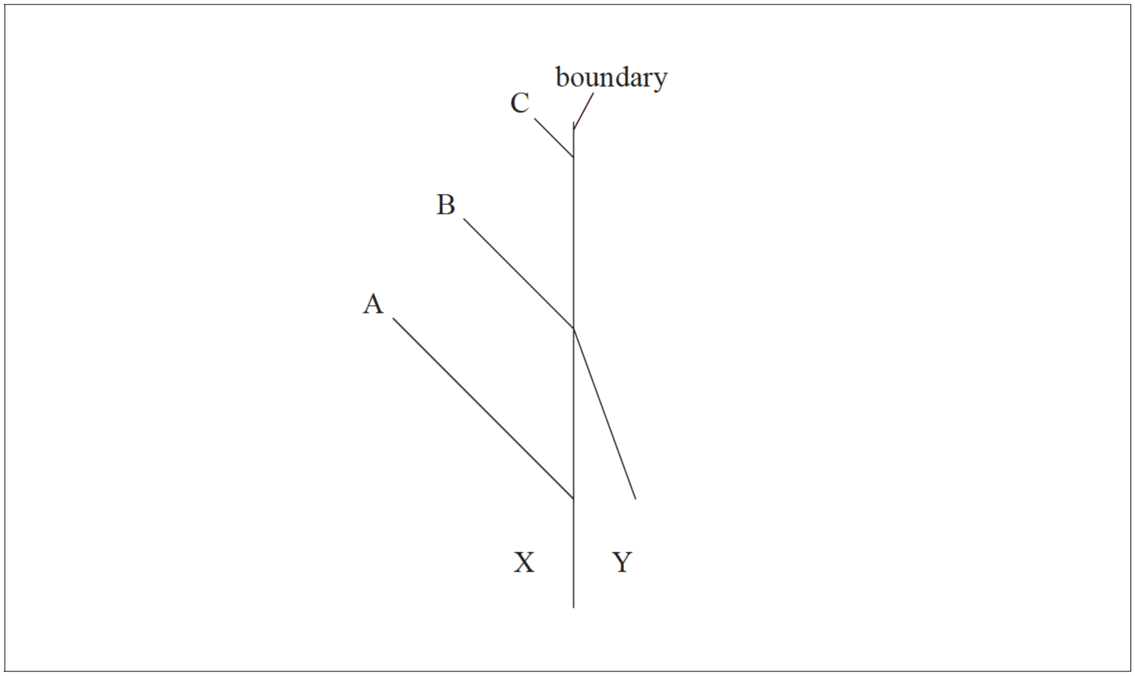
4b. The diagram shows three wavefronts, A, B and C, of a wave at a particular instant in time incident on a boundary between media X and Y. Wavefront B is also shown in medium Y. *[4 marks]*



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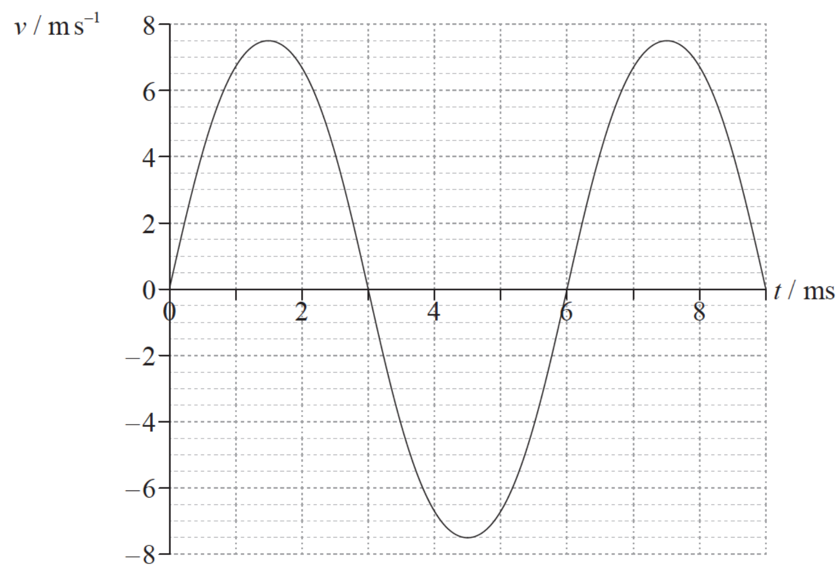
4d. The graph below shows the variation of the velocity *v* with time *t* for one oscillating particle of a medium. *[3 marks]*



(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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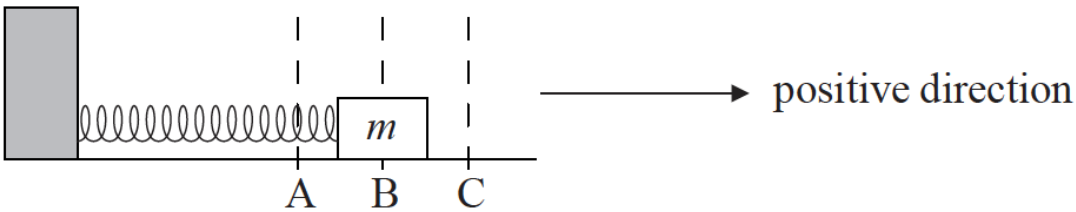
This question is in **two** parts. **Part 1** is about simple harmonic motion and the superposition of waves. **Part 2** is about gravitational fields.

Part 1 Simple harmonic motion and the superposition of waves

An object of mass *m* is placed on a frictionless surface and attached to a light horizontal spring. The other end of the spring is fixed.



The equilibrium position is at B. The direction B to C is taken to be positive. The object is released from position A and executes simple harmonic motion between positions A and C.

5a. Define *simple harmonic motion*. *[2 marks]*

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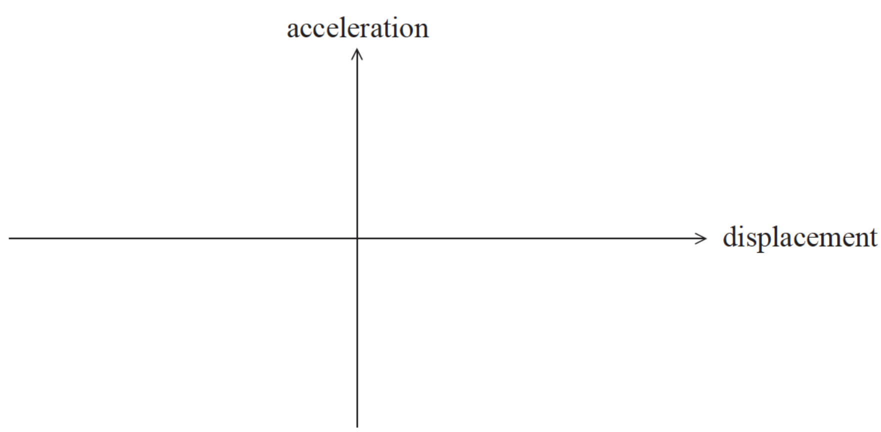
5b. (i) On the axes below, sketch a graph to show how the acceleration of the mass varies with displacement from the equilibrium position B. *[3 marks]*



(ii) On your graph, label the points that correspond to the positions A, B and C.

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5c. (i) On the axes below, sketch a graph to show how the velocity of the mass varies with time from the moment of release from A until the mass returns to A for the first time. *[3 marks]*

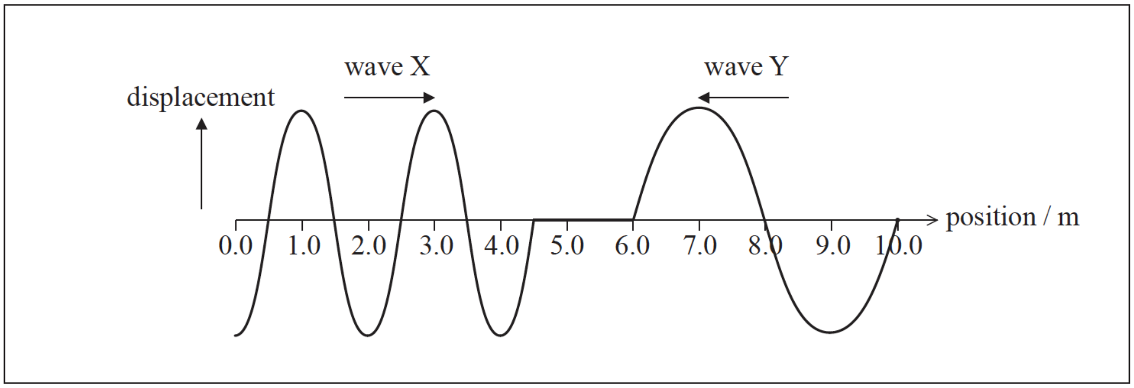
(ii) On your graph, label the points that correspond to the positions A, B and C.

5d. The period of oscillation is 0.20s and the distance from A to B is 0.040m. Determine the maximum speed of the mass. *[3 marks]*

5e. A long spring is stretched so that it has a length of 10.0 m. Both ends are made to oscillate with simple harmonic motion so that transverse waves of equal amplitude but different frequency are generated. *[4 marks]*

Wave X, travelling from left to right, has wavelength 2.0 m, and wave Y, travelling from right to left, has wavelength 4.0 m. Both waves move along the spring at speed 10.0 m s^{-1}.

The diagram below shows the waves at an instant in time.



(i) State the principle of superposition as applied to waves.

(ii) By drawing on the diagram or otherwise, calculate the position at which the resultant wave will have maximum displacement 0.20 s later.

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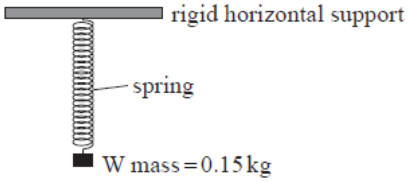
6a. One end of a light spring is attached to a rigid horizontal support. *[8 marks]*



An object W of mass 0.15 kg is suspended from the other end of the spring. The extension x of the spring is proportional to the force F causing the extension. The force per unit extension of the spring k is 18 Nm^{-1}.

A student pulls W down such that the extension of the spring increases by 0.040 m. The student releases W and as a result W performs simple harmonic motion (SHM).

(i) State what is meant by the expression “W performs SHM”.

(ii) Determine the maximum acceleration of W.

(iii) Determine the period of oscillation of the spring.

(iv) Determine the maximum kinetic energy of W.

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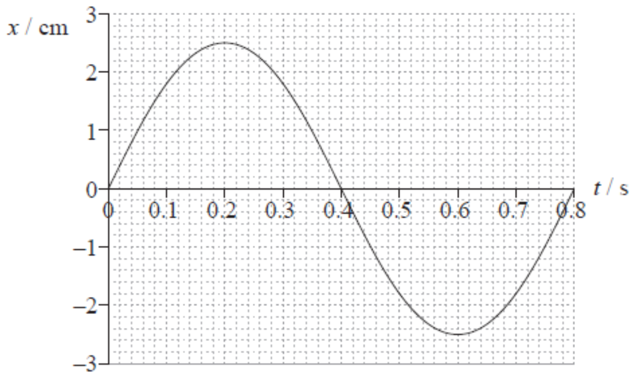
6b. A light spring is stretched horizontally and a longitudinal travelling wave is set up in the spring, travelling to the right. *[6 marks]*

(i) Describe, in terms of the propagation of energy, what is meant by a longitudinal travelling wave.

(ii) The graph shows how the displacement *x* of one coil C of the spring varies with time *t*.



The speed of the wave is 3.0 cms^{-1}. Determine the wavelength of the wave.

(iii) Draw, on the graph in (c)(ii), the displacement of a coil of the spring that is 1.8 cm away from C in the direction of travel of the wave, explaining your answer.

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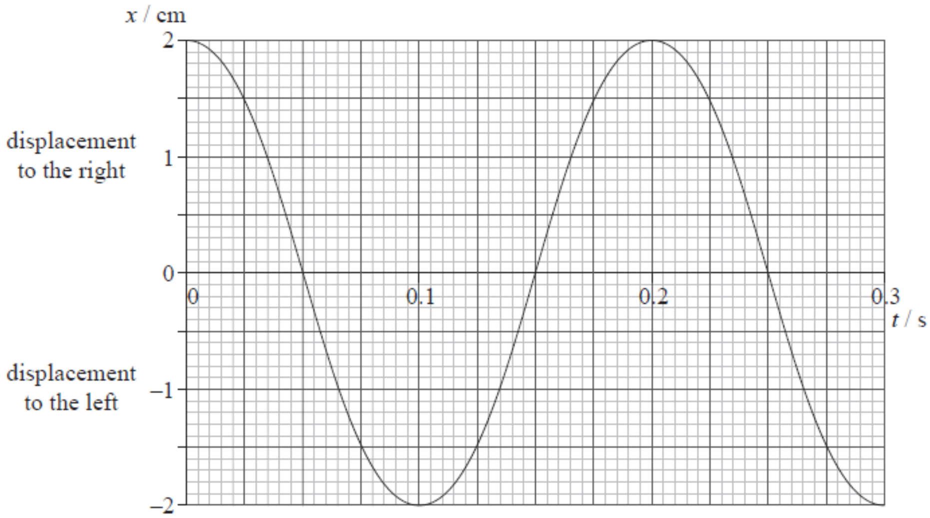
Part 2 Simple harmonic oscillations

A longitudinal wave travels through a medium from left to right.

Graph 1 shows the variation with time *t* of the displacement *x* of a particle P in the medium.

Graph 1



7a. For particle P, *[6 marks]*

(i) state how graph 1 shows that its oscillations are not damped.

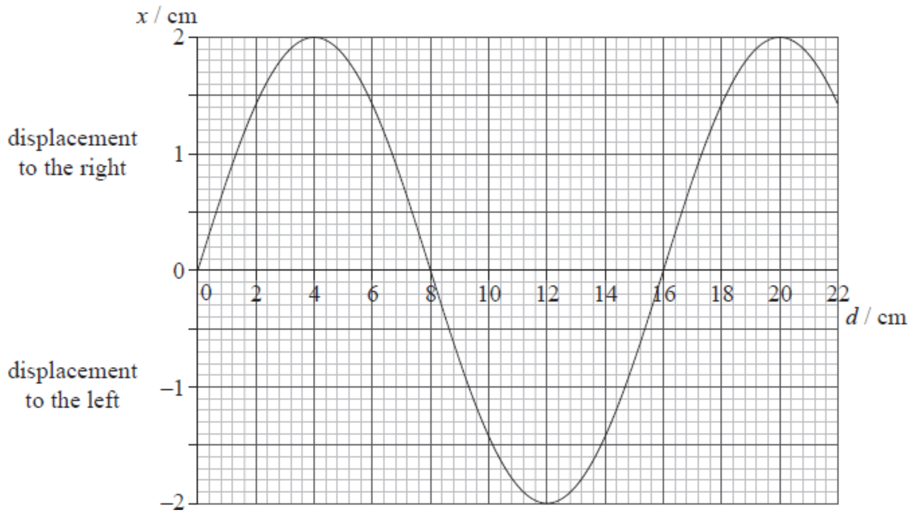
(ii) calculate the magnitude of its maximum acceleration.

(iii) calculate its speed at t=0.12 s.

(iv) state its direction of motion at t=0.12 s.

7b. Graph 2 shows the variation with position *d* of the displacement *x* of particles in the medium at a particular instant of time. *[4 marks]*

Graph 2



Determine for the longitudinal wave, using graph 1 and graph 2,

(i) the frequency.

(ii) the speed.

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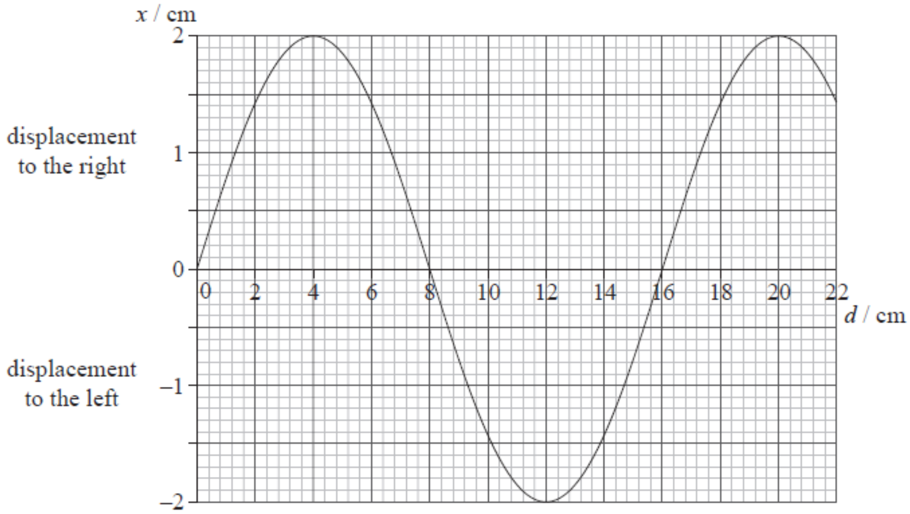
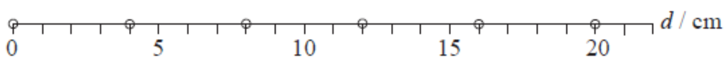
7c. **Graph 2** – reproduced to assist with answering (c)(i). *[4 marks]*



(c) The diagram shows the equilibrium positions of six particles in the medium.



(i) On the diagram above, draw crosses to indicate the positions of these six particles at the instant of time when the displacement is given by graph 2.

(ii) On the diagram above, label with the letter C a particle that is at the centre of a compression.