IB · HL · Physics

3 hours 14 questions

Structured Questions

Standing Waves & Resonance

Standing Waves / Nodes & Antinodes / Boundary Conditions for Standing Waves / Harmonics in Strings & Pipes / The Nature of Resonance / The Effect of Damping

Easy (5 questions)	/53
Medium (5 questions)	/49
Hard (4 questions)	/57
Total Marks	**/159**

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Easy Questions

1 (a) Standing waves are sometimes referred to as stationary waves.

State three conditions which are required for the formation of a standing wave.

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(3 marks)

(b) Standing waves can be thought of as the opposite of progressive waves.

Use the text in the box to complete the sentences below, comparing the two types of wave.

constant	**transfer**	**do not**
store	**do**	**different at different points**

(i) Standing waves ______ energy but progressive waves ______ energy.

[1]

(ii) The amplitude of a standing wave is ______ , whereas the amplitude of a progressive wave is ______ .

[1]

(iii) The crests of a standing wave ______ move along but simply oscillate up and down, while but the crests of a progressive wave ______ move along as the wave travels.

[1]

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(3 marks)

(c) A stationary wave is made up of nodes and anti-nodes. State the definitions of

(i) A node.

[1]

(ii) An antinode.

[1]

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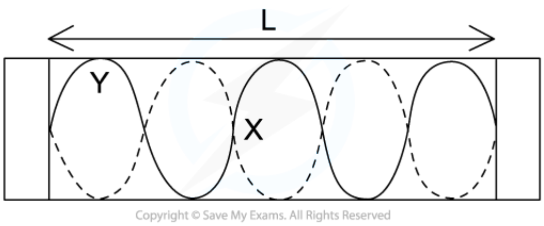
(2 marks)

(d) The length L shows 2.5 full wavelengths of a standing wave in a column of air.



(i) Identify the points marked X and Y.

[2]

(ii) State the boundary conditions for the formation of this standing wave.

[2]

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(4 marks)

2 (a) Standing waves are formed when waves undergo superposition.

State the principle of superposition.

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(3 marks)

(b) Name two types of waves which can undergo superposition.

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(2 marks)

(c) Distinguish between constructive interference and destructive interference.

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(2 marks)

(d) A standing wave representing the first harmonic is set up on a vibrating string.

State the number of nodes and anti-nodes which would appear on this wave.

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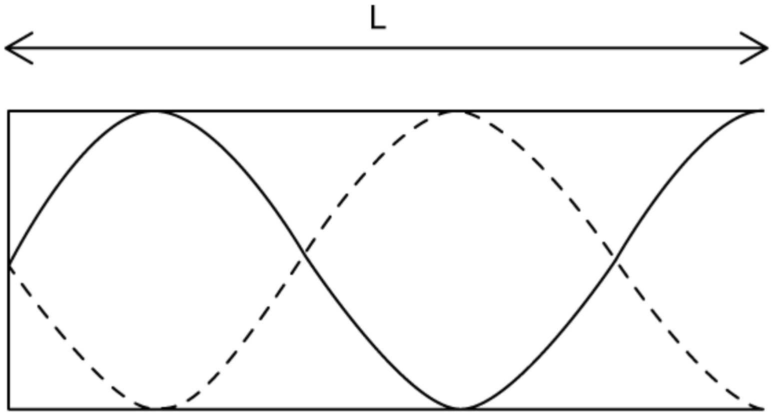
(2 marks)

3 (a) A standing wave is set up in a column of air within a pipe of length L, which is open at one end.



Giving your answer as a fraction of L, determine the wavelength, λ.

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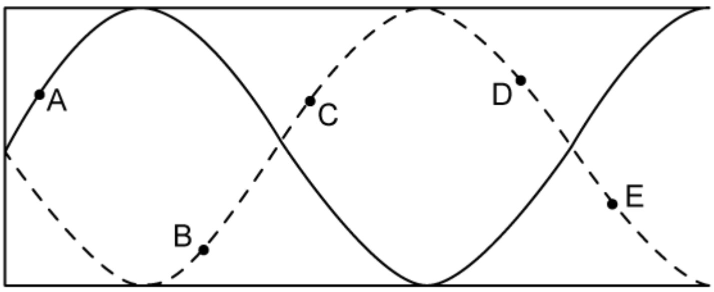
(2 marks)

(b) For the standing wave identify which points are in phase and which points are in anti-phase.



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(3 marks)

(c) The column of air is vibrated so that it oscillates at the third harmonic.

Sketch a diagram to show the shape of the wave produced in the pipe.

(3 marks)

(d) The column of air oscillating at the seventh harmonic has length L and velocity, v.

In terms of L and v, determine the

(i) Wavelength.

[1]

(ii) Frequency.

[1]

(2 marks)

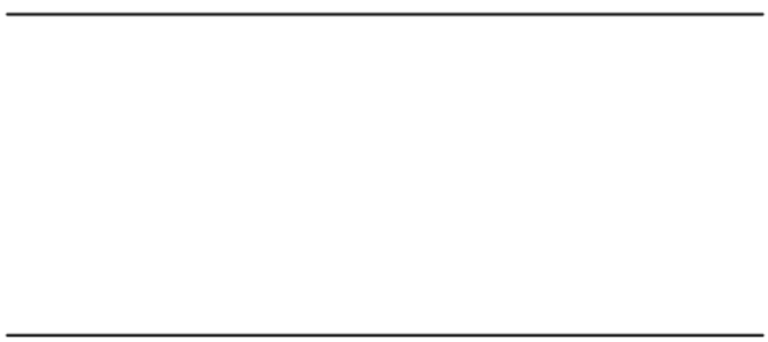
4 (a) Describe three methods that can be used to identify that two points on a standing wave are in phase.

(3 marks)

(b) Describe the boundary conditions for a standing wave in a pipe of air which is open at one end and closed at the other.

(2 marks)

(c) For a pipe that is open at both ends



(i) Sketch the first harmonic.

[2]

(ii) Write an expression for wavelength in terms of the length of the pipe, L.

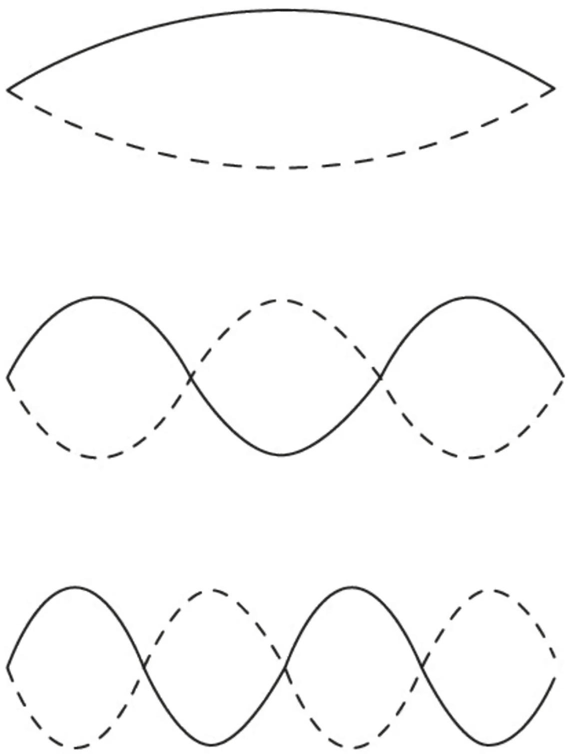
[1]

(3 marks)

(d) For a string which is fixed at both ends, sketch the third harmonic.

(3 marks)

5 (a) The diagram shows three possible harmonics on a string fixed at each end.



Identify the three harmonics.

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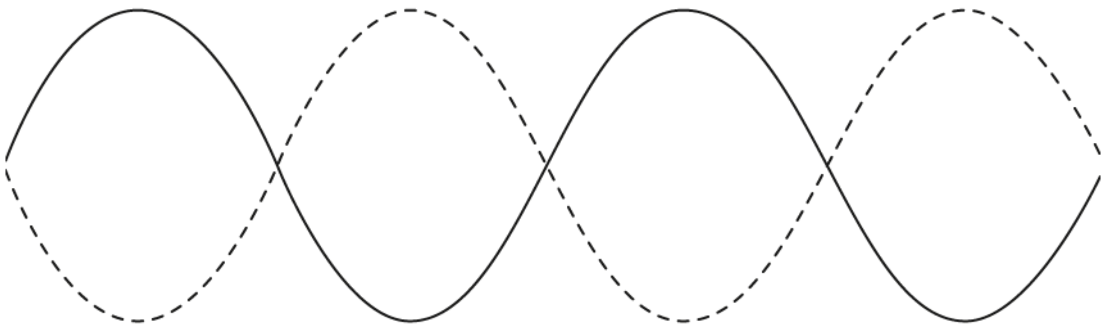
(3 marks)

(b) For the harmonic shown, identify an expression for the wavelength.



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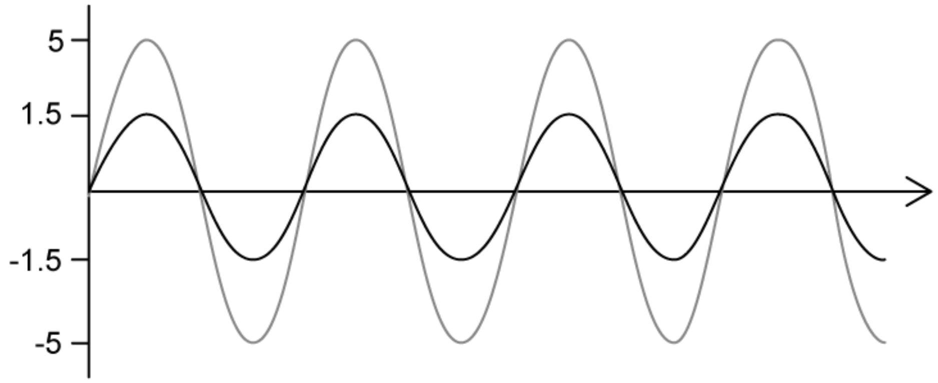
(3 marks)

(c) The diagram shows two waves which are travelling in phase.



Sketch the resultant wave, including labelling the axes with relevant quantities.

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(3 marks)

(d) Stationary waves are formed when two waves travelling on the same line superpose.

Identify two conditions which must be true for superposition to occur.

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(2 marks)

Medium Questions

1 (a) A standing wave is created in an open pipe that is open at both ends and placed within a chamber filled with an unknown gas. The pipe has a length of 45 cm and the fundamental frequency in this pipe is 381 Hz.

Calculate the speed of this standing wave.

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(2 marks)

(b) Calculate the wavelength of the fourth harmonic for this pipe.

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(2 marks)

(c) Calculate the frequency of the sixth harmonic.

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(2 marks)

(d) The pipe is now submerged and filled with water.

If the speed of sound in the water is 1500 m s^{-1}, deduce the period of the fundamental frequency in this pipe.

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(3 marks)

2 (a) A speaker is set-up directly above the top of a vertical pipe which is partially filled with water.

Initially, there is a strong sound heard from the pipe when the distance between the loudspeaker and the water is 83 cm. This is the longest length for which a strong sound is heard.

As the pipe is filled with more water, a second strong sound is heard from the pipe when the distance between the loudspeaker and the water is 67 cm.

Outline how a standing wave is created between the speaker and the surface of the water.

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(2 marks)

(b) Predict the distance between the speaker and the water at which the next strong sound will be produced as the pipe is filled water.

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(2 marks)

(c) The air within the pipe and the water at the bottom of the pipe are both heated to 70 °C. The speed of sound in this warmer air is 371 m s^{-1} and the speaker now plays a sound at a constant frequency of 600 Hz.

The speaker is brought down to the surface of the water and slowly raised until a strong sound is produced. The distance between the surface of the water and the speaker is 15.5 cm when this occurs. State what is causing the strong sound and estimate the wavelength of this sound.

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(2 marks)

(d) If the water volume is kept constant, predict the distance that the speaker must be raised for the next strong sound to be produced and outline what causes this strong sound.

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(2 marks)

3 (a) Explain clearly how the following vary in a stationary wave:

- Amplitude
- Phase
- Energy transfer

(3 marks)

(b) A stationary wave in the third harmonic is formed on a stretched string.

Discuss the formation of this wave and its properties. Your answer must include:

- An explanation of how the stationary wave is formed
- A description of the features of this particular harmonic of the stationary wave

(4 marks)

(c) On the diagram shown, draw the stationary wave that would be formed on the string in part (b) with two more nodes and two more antinodes. State the harmonic of this new stationary wave.

(2 marks)

(d) Calculate the length of the string in part (c) if it oscillates at 500 cycles per second and the speed of waves travelling within it is 140 m s^{-1}

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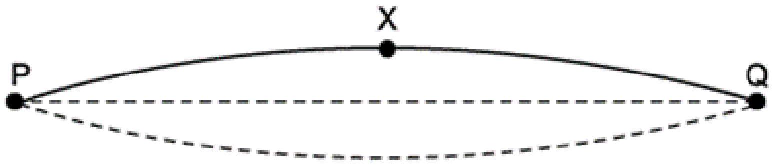
(2 marks)

4 (a) The diagram represents a stationary wave formed on a violin string fixed at **P** and **Q** when it is plucked at its centre. **X** is a point on the string at maximum displacement.



Explain why a stationary wave is formed on the string.

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(3 marks)

(b) The stationary wave formed represents the "A" string of a violin which has a frequency of 440 Hz.

Calculate the time taken for the string at point **X** to move from maximum displacement to its next maximum displacement.

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(3 marks)

(c) The progressive waves on the "A" string travel at a speed of 280 m s^{-1}.

Calculate the length of the "A" string.

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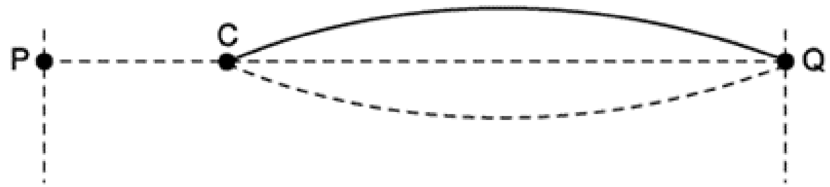
(3 marks)

(d) This diagram shows the string between **P** and **Q**.

A violinist presses on the string at **C** to shorten it and create the higher "B" note. The distance between **C** and **Q** is 0.252 m.

The speed of the progressive wave remains at 280 m s^{-1} and the tension remains constant.



Calculate the frequency of the note "B".

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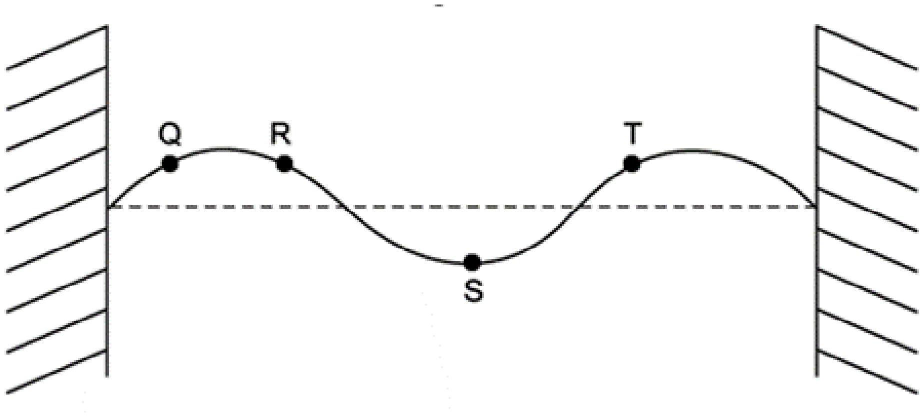
(3 marks)

5 (a) The diagram shows the appearance of a stationary wave on a stretched string at one instant in time. In the position shown each part of the string is at a maximum displacement.



Mark clearly on the diagram the direction in which points **Q**, **R**, **S** and **T** are about to move.

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(2 marks)

(b) In the diagram from part (a), the frequency of vibration is 240 Hz.

Calculate the frequency of the second harmonic for this string.

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(2 marks)

(c) The speed of the transverse waves along the string is 55 m s^{-1}.

Calculate the length of the string.

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(3 marks)

(d) Compare the amplitude and phase of points **R** and **S** on the string in the diagram used in part (a).

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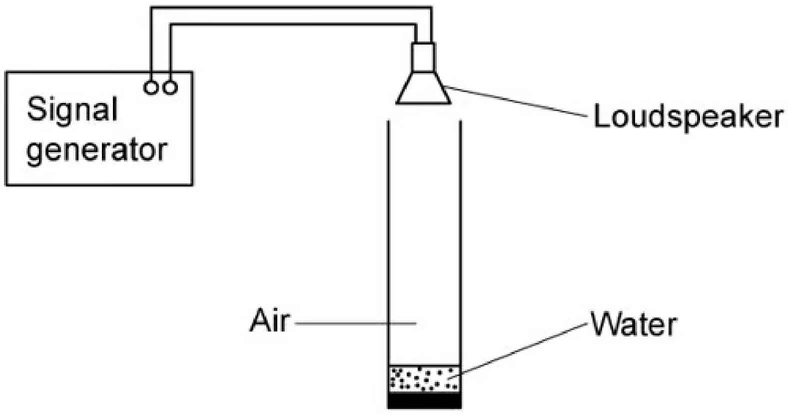
(2 marks)

Hard Questions

1 (a) A physics class investigates stationary waves in air using a tall tube of cross-sectional area 3.0×10^{-3} m^2 and a loudspeaker connected to a signal generator. Initially the tube is empty of water. The signal generator is switched on so that sound waves enter the tube. Water is slowly poured into the tube.



The class notice that the sound gradually increases in volume, reaching a first maximum at a particular instant. Immediately after the volume begins to decrease. Water continues to be added until the volume rises again, reaching a second and final maximum after a further 2.5×10^{-3} m^3 of water is poured in.

Determine the wavelength of the sound waves.

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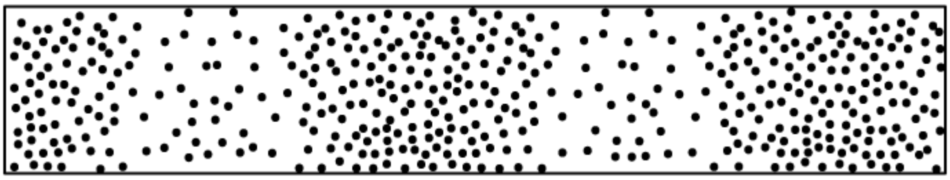
(2 marks)

(b) One method of illustrating sound waves is shown.



Sketch the diagram labelling all the positions of the nodes formed by the standing wave in part (a).

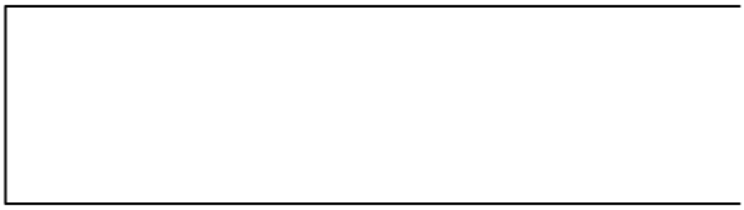
(3 marks)

(c) The teacher asks whether the positions of the nodes and antinodes are related to regions of pressure along the standing wave.

By analysing the diagram from part (b) discuss the correct response.

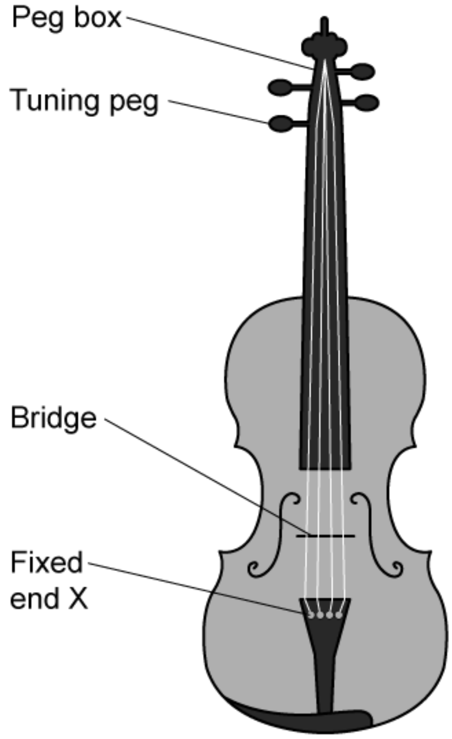
(4 marks)

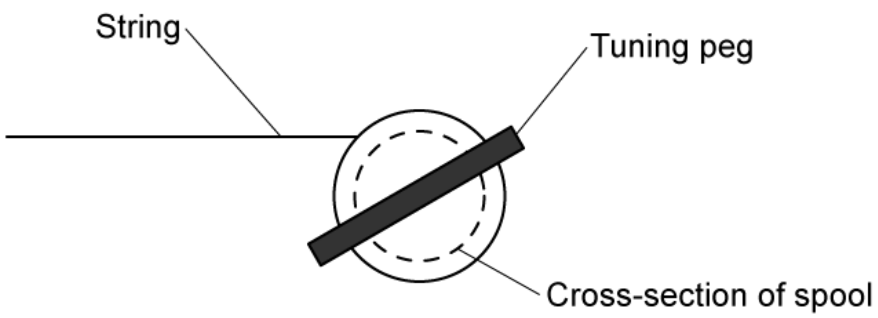
(d) Using the diagram shown, sketch the shape of the stationary sound wave the students discussed in the previous part.



(4 marks)

2 (a) The diagrams show the structure of a violin and a close-up of the tuning pegs.





The strings are attached at end X then pass over a bridge which acts as a fixed point. The strings are also fixed at the other end, where they are wound around cylindrical spools, fixed to tuning pegs.

Strings for musical instruments create notes according to their tension and a property of the string called mass per unit length, μ.

The properties of the string and the frequency of the first harmonic are related by the equation:

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

Where f = frequency of first harmonic (Hz), L = length (m), T = tension (N) and μ = mass per unit length (kg m^{-1}).

The mass of a particular string is 1.4×10^{-4} kg and it has a vibrating length of 0.35 m. When the tension in the string is 25 N, it vibrates with a first-harmonic frequency of 357 Hz.

When the tension in the string is 50 N

(i) Calculate the mass per unit length, μ of the string.

[2]

(ii) Using the equation provided, calculate the speed at which waves travel along the string.

[3]

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(5 marks)

(b) Show that the first harmonic frequency doubles when the tension in the string quadruples.

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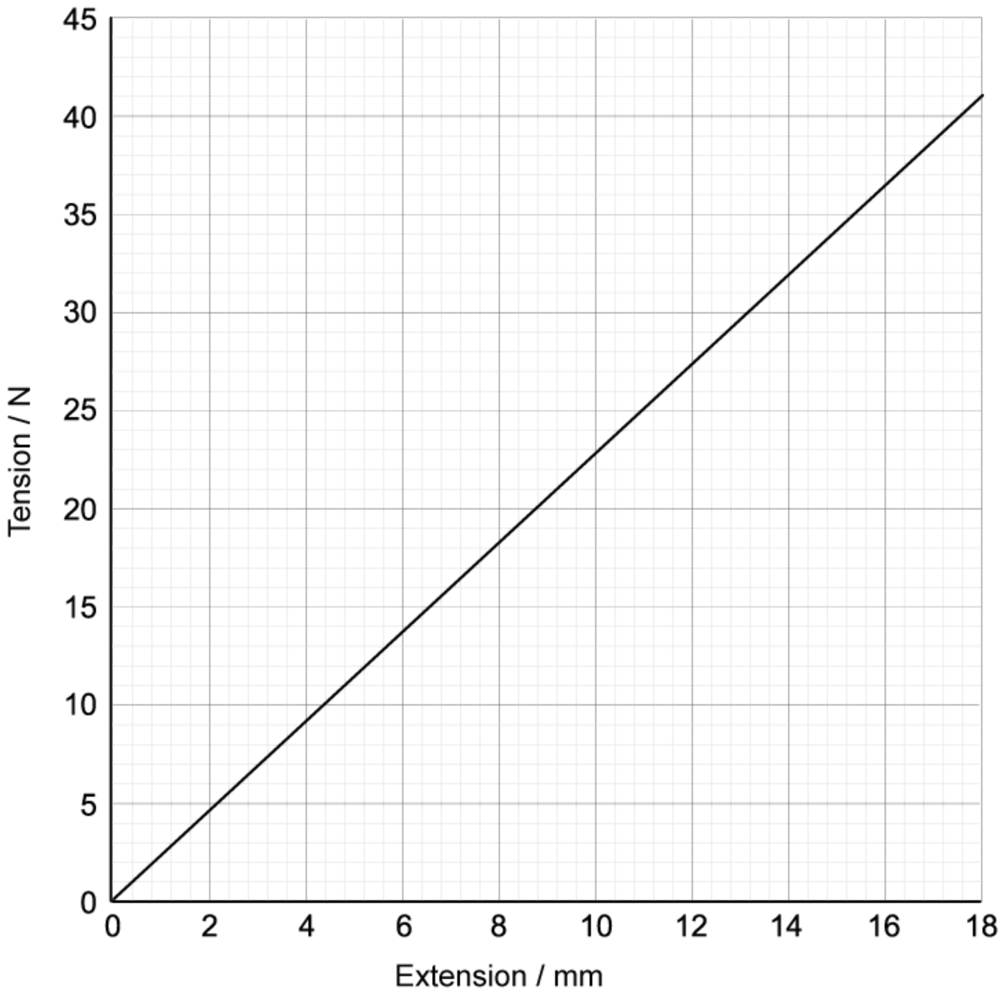
(4 marks)

(c) The graph shows how the tension in the string varies with the extension of the string.



The string, under its original tension of 25 N is vibrating at a frequency of 357 Hz. The diameter of the cylindrical spool is 6.50×10^{-3} m.

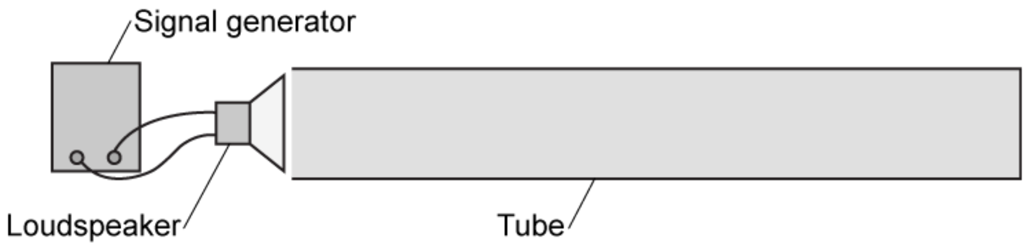
Determine the higher frequency that is produced when the tuning peg is rotated through an angle of 60 °.

(5 marks)

(d) State and explain the assumption that must be made in order to carry out the calculation in part (c).

(2 marks)

3 (a) The diagram shows a common piece of teaching laboratory equipment which can be used to demonstrate wave phenomena.



Explain how waves from the loudspeaker form stationary waves in the tube. Include in your answer a condition for formation of the wave and describe the wave which is formed.

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(3 marks)

(b) For the third harmonic of the wave formed construct a three-part diagram clearly linking the wave shape, node formation and pressure differences within the tube. Start with the template provided below.

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(5 marks)

(c) The speed of sound in the tube is 340 m s^{-1} and the frequency of the sound emitted by the loudspeaker is 880 Hz.

For this equipment calculate

(i) The length of the tube, giving the answer in cm.

[2]

(ii) The wavelength of the fifth harmonic, giving the answer in S.I. units.

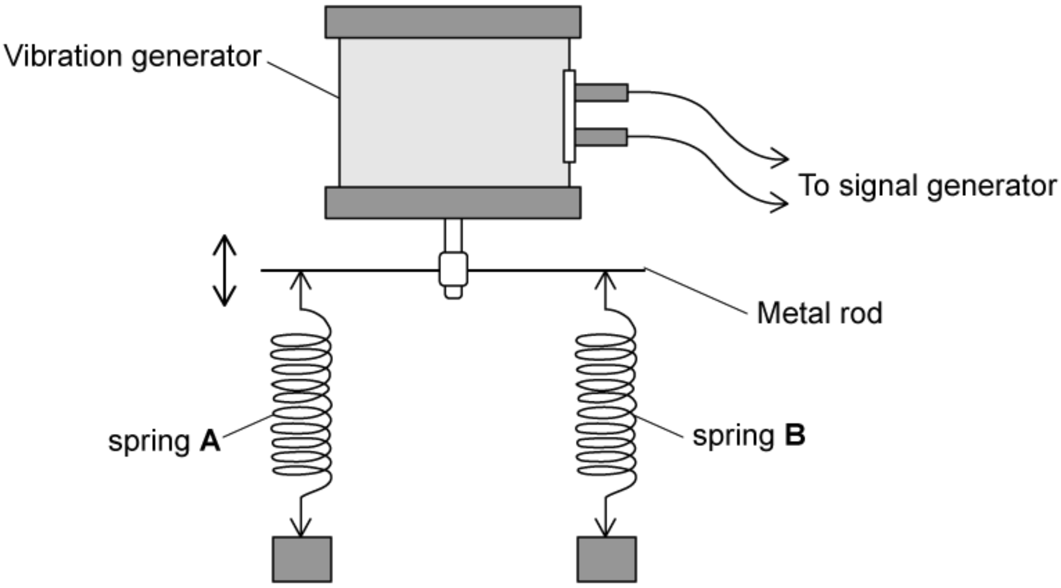
[2]

(4 marks)

4 (a) A student is investigating forced vertical oscillations in springs.

Two springs, A and B, are suspended from a horizontal metal rod that is attached to a vibration generator. The stiffness of A is 3k, and the stiffness of B is k.

Two equal masses are suspended from the springs.



The vibration generator is connected to a signal generator. The signal generator is used to vary the frequency of vibration of the metal rod. When the signal generator is set at 6.5 Hz, the mass attached to spring A oscillates with a maximum amplitude of 4.0 cm.

Calculate the frequency at which the mass attached to spring B oscillates with maximum amplitude.

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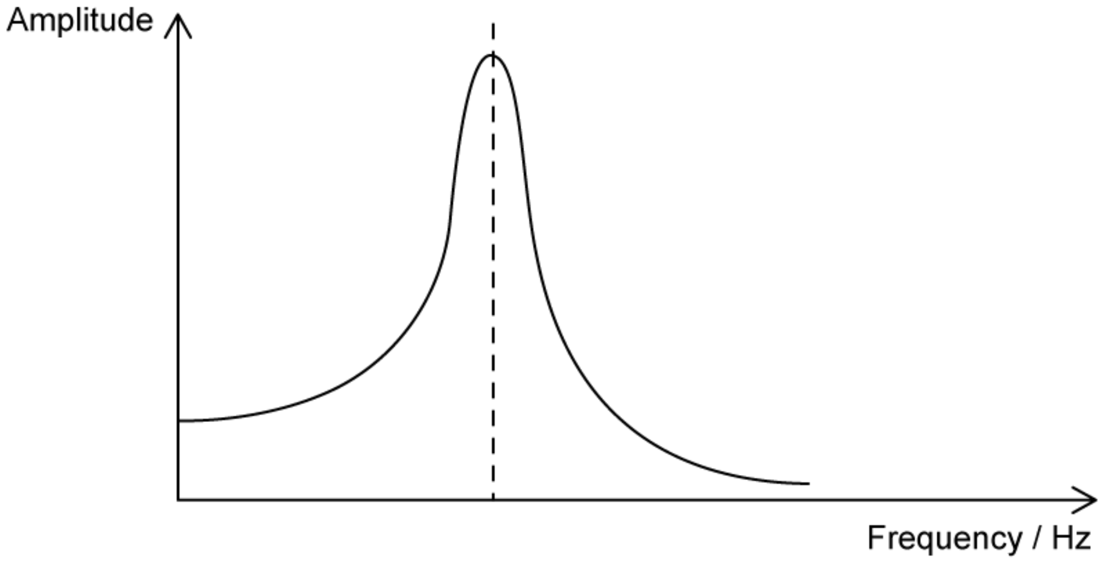
(2 marks)

(b) The investigation is repeated with the mass attached to spring A immersed in a beaker of oil.

A graph of the variation of the amplitude with frequency for spring A is different for spring B.



(i) Sketch the variation of this graph for spring A.

[3]

(ii) Explain two differences between the two graphs.

[3]

(5 marks)

(c) (i) Sketch the graph of displacement against time for spring A after it has been immersed in a beaker of oil starting at its lowest point.

[3]

(ii) Explain in terms of energy the reasons behind the graph you have drawn.

[3]

(6 marks)

(d) When immersed in the beaker of oil, spring A is released with the same amplitude as when it was connected to the vibration generator.

Calculate the fraction of the energy lost in the oil when the amplitude of oscillations is 0.9 cm.

(3 marks)