4.5 Standing Waves

Question Paper

Course	DP IB Physics
Section	4. Waves
Topic	4.5 Standing Waves
Difficulty	Hard

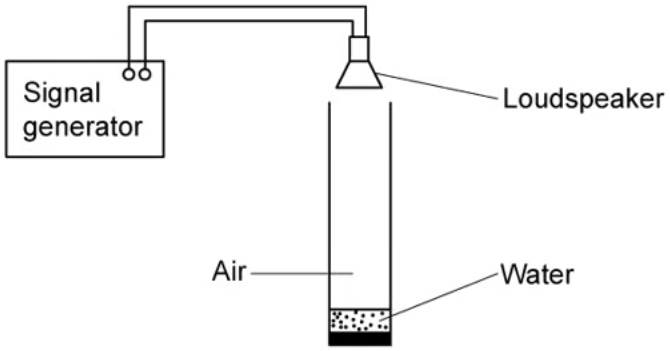
Time allowed: 50

Score: /41

Percentage: /100

Question 1a

A physics class investigates stationary waves in air using a tall tube of cross-sectional area $3.0 \times 10^{-3}\ m^2$ 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 $2.5 \times 10^{-3}\ m^3$ of water is poured in.

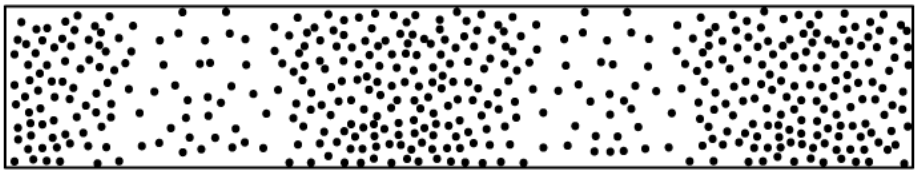
(a)
Determine the wavelength of the sound waves.

[2]

[2 marks]

Question 1b

One method of illustrating sound waves is shown.



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

[3]

[3 marks]

Question 1c

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

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

[4]

[4 marks]

Question 1d

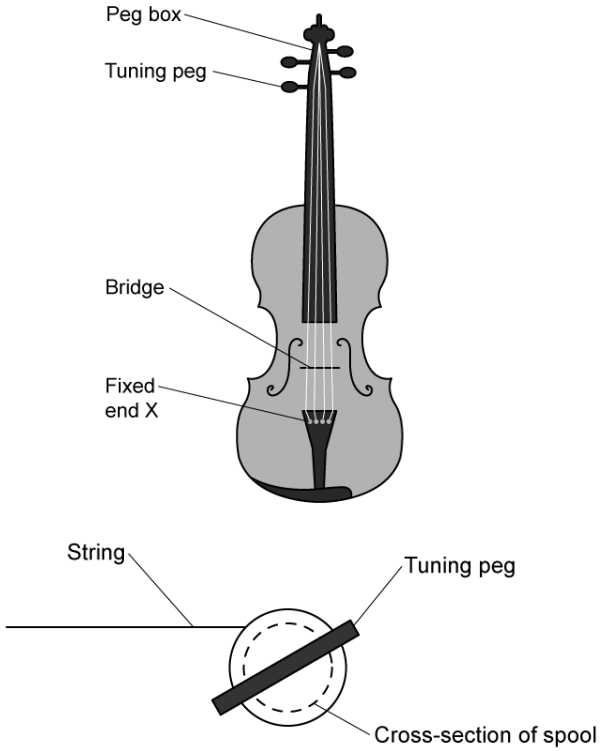
(d)
Using the diagram shown, sketch the shape of the stationary sound wave the students discussed in the previous part.

[4]

[4 marks]

Question 2a

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.

(a)
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]

[5 marks]

Question 2b

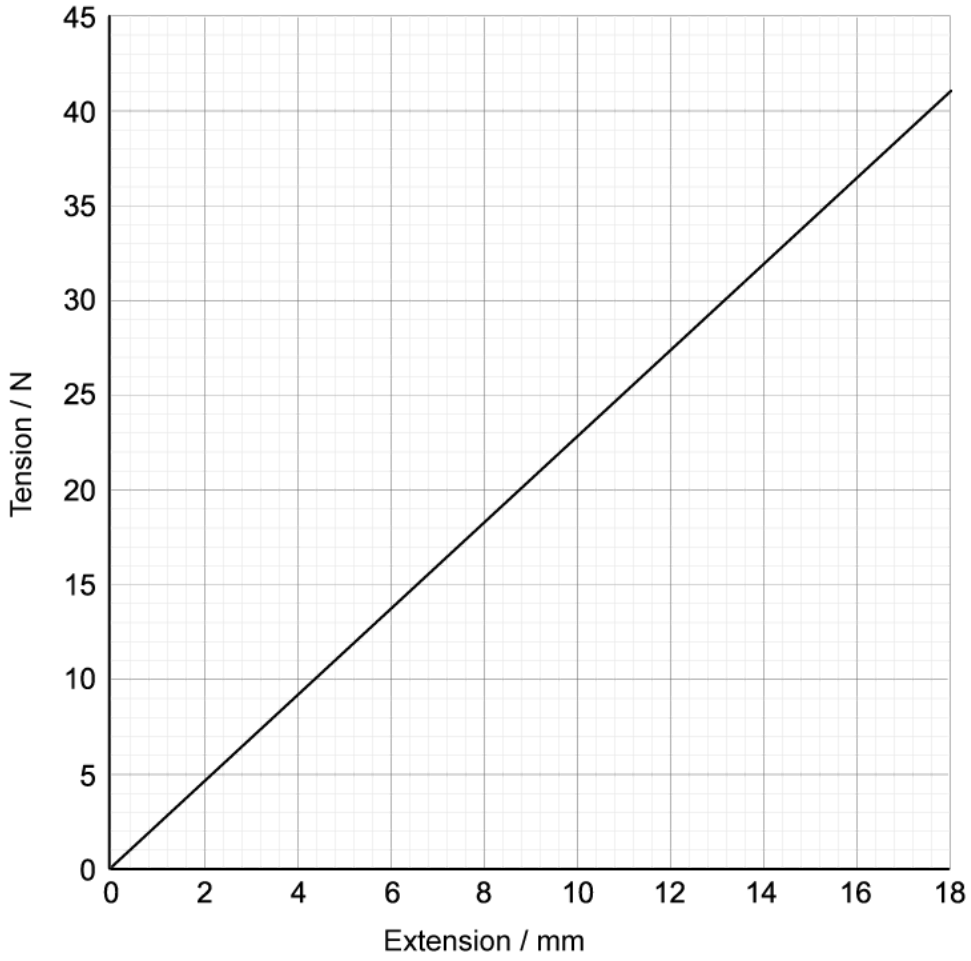
(b)
Show that the first harmonic frequency doubles when the tension in the string quadruples.

[4]

[4 marks]

Question 2c

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.

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

[5]

[5 marks]

Question 2d

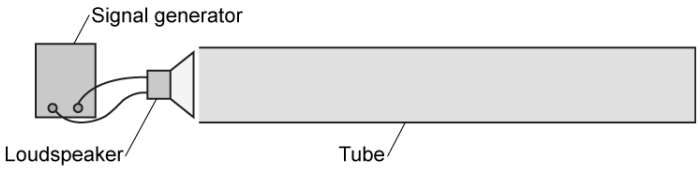
(d)
State and explain the assumption that must be made in order to carry out the calculation in part (c).

[2]

[2 marks]

Question 3a

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



(a)
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.

[3]

[3 marks]

Question 3b

(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.

[5]

[5 marks]

Question 3c

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.

(c)
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]