1(a). A flute is a musical instrument made from a long tube that is open at both ends.

A stationary sound wave in the tube produces a musical note.

The lowest frequency note that a standard flute produces in air is 262 Hz.

The speed of sound in air at a temperature of 20°C is 340 m s^{-1}.

Show that a standard flute has an approximate length of 0.65 m.

[3]

(b). In an ideal gas, the speed *v* of sound is given by

$$v = \left(\frac{\gamma RT}{M}\right)^{1/2}$$

where

γ is a dimensionless constant that depends on the gas

R is the molar gas constant

T is the absolute temperature

M is the molar mass of the gas.

The table below shows values of γ and *M* for both air and helium.

Gas	**γ**	***M*/g mol⁻¹**
Air	1.40	29.0
Helium	1.67	4.00

i. The kinetic model of an ideal gas assumes that there are a large number of particles in rapid, random motion.

State **two** further assumptions for the kinetic model of an ideal gas.

1 ______________________________

____

2 ______________________________

______________________________ **[2]**

ii. A standard flute is placed inside a sealed chamber.

The chamber is filled with helium at a temperature of −10°C.

Calculate the lowest frequency that the flute could produce inside the chamber.

frequency = ... Hz **[4]**

2. A stationary sound wave is created in air.

The distance between two adjacent nodes of the stationary wave is 0.7 m.

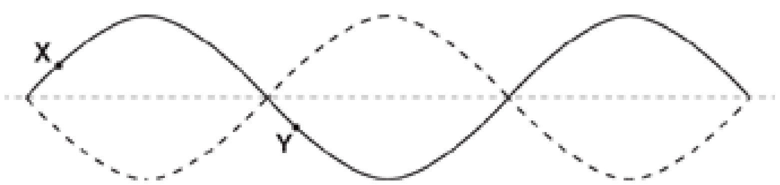
What is the frequency of the sound wave?

Speed of sound in air = 340 ms^{-1}

A 243 Hz
B 476 Hz
C 486 Hz
D 971 Hz

Your answer ☐ **[1]**

3. The diagram shows a stationary wave on a string.



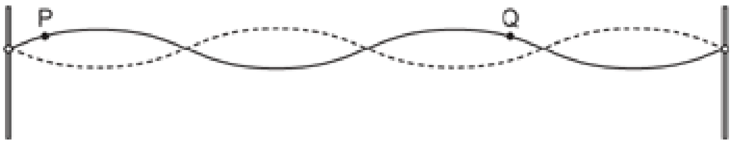
What is the phase difference between the points on the wave labelled **X** and **Y**?

A 0
B $\frac{\pi}{4}$
C $\frac{\pi}{2}$
D π

Your answer ☐ **[1]**

4. The diagram shows a string stretched between two posts.

The string is plucked and a stationary wave is set up.



What is the phase difference between P and Q?

A 0 rad
B $\frac{\pi}{4}$ rad
C $\frac{\pi}{2}$ rad
D π rad

Your answer **[1]**

5(a). A stationary sound wave is set up in a closed resonance tube as shown in **Fig. 6.1.**

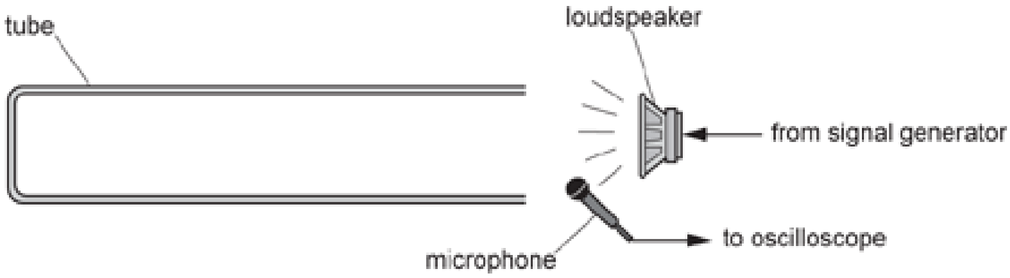


Fig. 6.1.

Sound is produced by a signal generator connected to a loudspeaker. The sound is detected by a microphone connected to an oscilloscope.

The time-base setting on the oscilloscope is 1 ms cm^{-1}.

The signal generator is adjusted until the fundamental mode of vibration is detected. **Fig. 6.2** shows the trace on the oscilloscope.

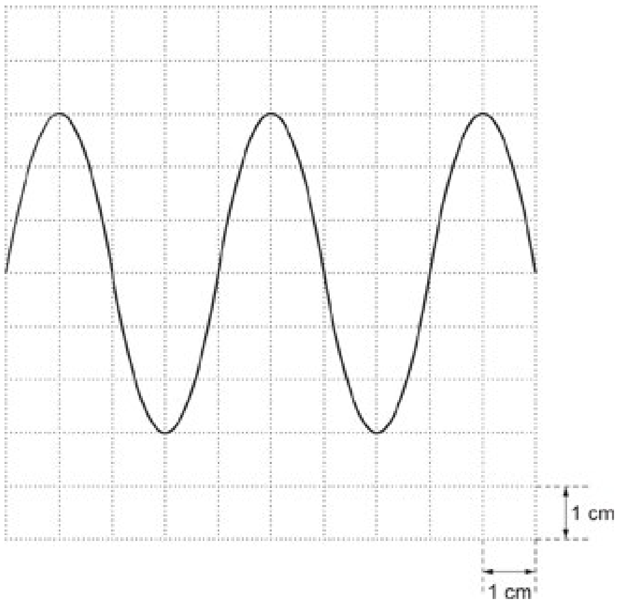


Fig. 6.2

Use **Fig. 6.2** to determine the frequency f_0 of the fundamental mode of vibration.

f_0 = ... Hz **[2]**

(b). Draw on Fig. 6.3 the stationary wave pattern for the fundamental mode of vibration.

Label on Fig. 6.3 the positions, if any, of any nodes **N** and any antinodes **A**.

Fig. 6.3

[2]

(c). The frequency of the signal generator is increased until the next harmonic is displayed on the oscilloscope.

Calculate the frequency f_n of the next harmonic.

f_n = ... Hz **[1]**

6. A student carries out an experiment to determine the speed *v* of sound in air. The student forms stationary sound waves in a resonance tube with water at the bottom as shown in **Fig. 7.1**.

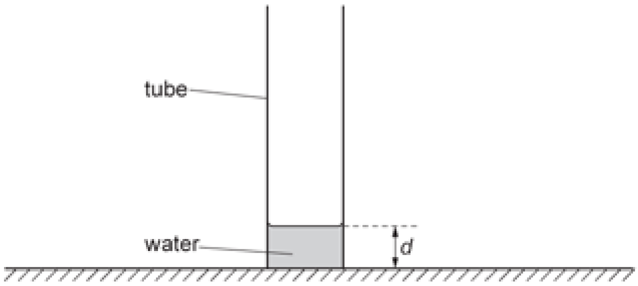


Fig. 7.1

The depth of the water is *d*.

Sound is produced by a signal generator connected to a loudspeaker. The sound is detected by a microphone connected to an oscilloscope.

The signal generator is adjusted. The frequency *f* of the fundamental mode of vibration of the sound in air is determined.

The experiment is repeated for different values of *d*.

The table shows the results. Values of $\frac{1}{f}$ have been included.

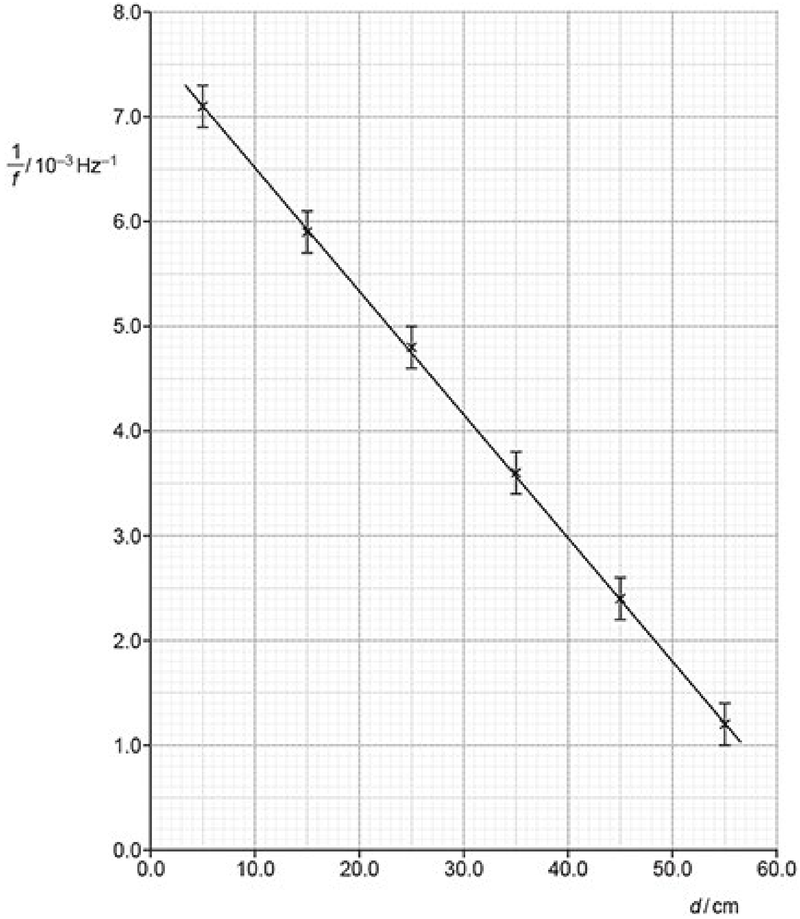
d / cm	f / Hz	$\frac{1}{f}$ / 10^{-3} Hz^{-1}
5.0	140	7.1 ± 0.2
15.0	170	5.9 ± 0.2
25.0	210	4.8 ± 0.2
35.0	280	3.6 ± 0.2
45.0	420	2.4 ± 0.2
55.0	840	1.2 ± 0.2

It is suggested that the relationship between *f* and *d* is

$$\frac{1}{f} = -\frac{4d}{v} + c$$

where *v* is the speed of sound in air and *c* is a constant.

A graph of $\frac{1}{f}$ / 10^{-3} Hz^{-1} on the *y*-axis against *d* / cm on the *x*-axis is plotted as shown below.

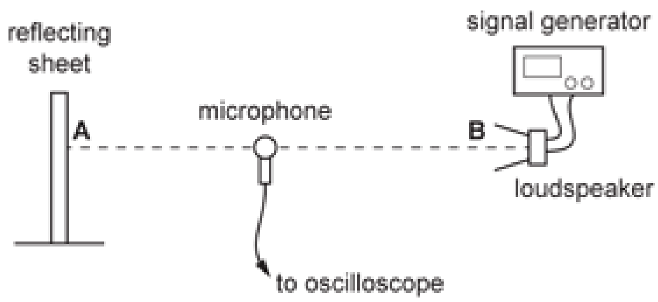


Explain how the apparatus is used to determine *f* **and** use the graph to determine *v*. Include the percentage uncertainty in your value of *v*.

[6]

7. Sound waves in air are longitudinal waves consisting of compressions and rarefactions.

A student investigates sound waves. They set up the following apparatus.



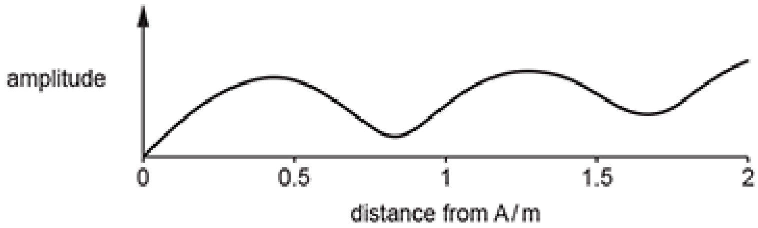
The sound wave emitted from the loudspeaker at **B** travels to the reflecting sheet at **A** and is reflected. A stationary wave is formed between the loudspeaker and the sheet.

The student moves a microphone along the line **AB**. The microphone is connected to an oscilloscope. The oscilloscope shows the relative amplitude of the stationary wave at each point along the line. The student observes a series of nodes and antinodes.

i. Explain how a stationary wave with nodes and antinodes is formed.

[3]

ii. The student measures the amplitude of the stationary wave at a range of distances from the reflecting sheet **A**. Their results are shown below.



The amplitudes at the nodes are observed to be:

- not exactly equal to zero
- closer to zero at distances closer to the reflecting sheet.

Explain these observations.

____ **[3]**

iii. The student measures the distance between two adjacent nodes as 0.84 m.

The frequency of the sound wave is 200 Hz.

Use these measurements to calculate a value for the speed of sound waves in air.

speed of sound waves = ... m s $^{-1}$ **[2]**

iv. The student wants to reduce the uncertainty in their calculated value for the speed of sound waves in air.

Suggest a suitable improvement to the student's method.

____ **[1]**

8(a). The figure below represents a tube open at both ends.

Air inside the tube is forced to oscillate by a speaker and produces a standing wave.

The length of the tube is 30.0 cm.

The wave speed inside the tube is 340 ms^{-1}.

On The figure sketch the standing wave for the fundamental mode of vibration.

[1]

(b). Calculate the frequency f_0 of the speaker that is producing the standing wave inside the tube.

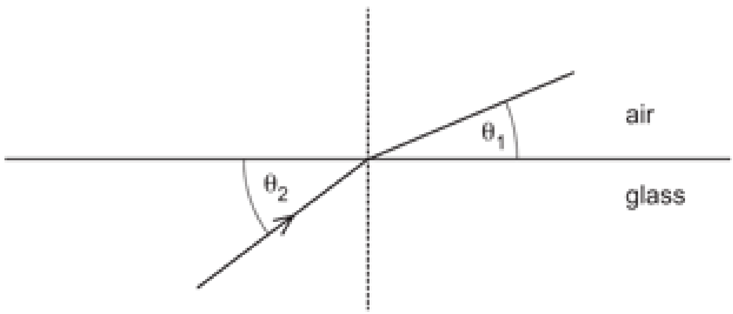
f_0 = ... Hz **[1]**

(c). The frequency of the speaker is increased.

Calculate the next frequency f_1 that will produce a standing wave in this tube.

f_1 = ... Hz **[2]**

9. A ray of light is travelling through glass with refractive index n = 1.51. The diagram (not to scale) shows light incident on a glass / air interface.



Which of these statements is/are true?

1 wavelength of light in glass < wavelength of light in air
2 $n_{glass} = 2n_{air}$
3 $\theta_2 > 48°$

A 1 only
B 1 and 2
C 3 only
D 1 and 3

Your answer [1]

10.

A student is doing an experiment to determine the speed of sound in air by producing stationary waves inside a horizontal glass tube.

Fine powder is sprinkled inside the tube. A loudspeaker is placed close to the open end of the tube. The other end of the tube is closed. The loudspeaker is connected to a signal generator producing a frequency of 2.72 kHz. The powder inside the tube forms piles at certain locations inside the tube, see **Fig. 16. 2**.

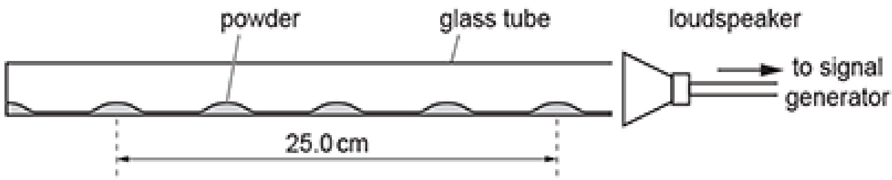


Fig. 16.2 (not to scale)

i. Suggest why the powder piles up at the nodes within the tube.

____ **[1]**

ii. Use **Fig. 16. 2** to determine the speed of sound v.

v = ... ms^{-1} **[3]**

iii. Determine the fundamental (minimum) frequency f_0 of the stationary wave that can be formed within this tube.

f_0 = ... Hz **[2]**

11(a).

Stationary waves are formed on the surface of seawater in a harbour as incoming waves are reflected off the harbour wall.

An observer is looking at these stationary waves.
State how the observer can tell that these are stationary waves.

[1]

(b). A wire is fixed between two supports, as shown in **Fig. 24**.

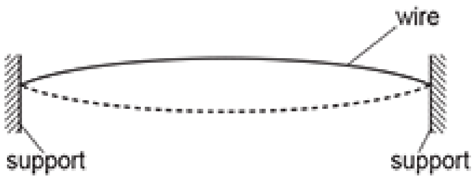


Fig. 24.

The wire is plucked in the middle. A stationary wave of fundamental frequency *f* is formed on the stretched wire.

The tension *T* in the stretched wire is given by the expression $T = 4f^2 mL$, where *f* is the frequency of the oscillating wire, *m* is the mass of the wire and *L* is the length of the wire.

A student is performing an experiment to determine the tension *T* in the wire. The measurements are shown in the table below.

Quantity	Measurement	Percentage uncertainty
f	58 Hz	2.5
m	9.7×10^{-4} kg	1.0
L	0.62m	0.5

i. Suggest how the student may have determined the fundamental frequency of the oscillating wire in the laboratory.

[2]

ii. Use the data in the table to determine

1 the wavelength of the progressive waves on the stretched wire

wavelength = ... m **[1]**

2 the speed of the progressive waves on the stretched wire

speed = ... m s^{-1} **[2]**

3 the **absolute** uncertainty in the tension *T*. Write your answer to 2 significant figures.

absolute uncertainty in *T* = ... N **[2]**

12. A student is experimenting with sound waves of wavelength 3.0 cm and electromagnetic waves also of wavelength 3.0 cm.

Which statement is correct about **both** of these waves?

A They can be polarised.
B They can form stationary waves.
C They have the same frequency.
D They have the same speed.

Your answer ☐ **[1]**

END OF QUESTION PAPER