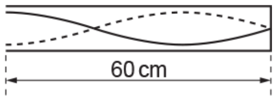
Stationary Waves

1. The diagram below shows a stationary wave pattern for a sound wave in a tube. The tube has one open end and one closed end.



The length of the tube is 60 cm.
What is the wavelength of the sound?

A 20 cm
B 40 cm
C 60 cm
D 80 cm

Your answer [1]

2. This question is about progressive waves and stationary waves.

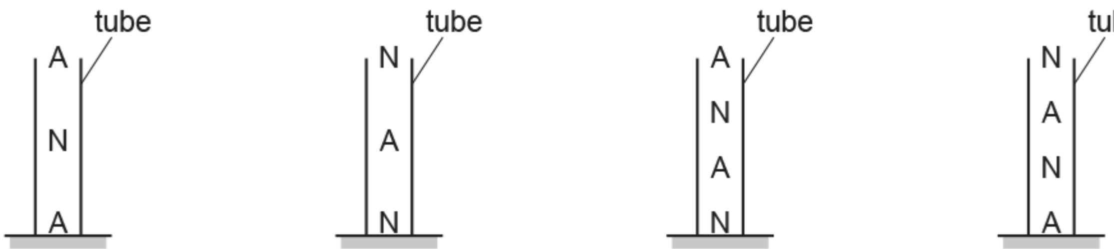
Which statement is **not** correct?

A A progressive wave transports energy through space.
B A stationary wave must have at least one node.
C For both waves, the amplitude of the oscillation is the same everywhere along the wave.
D In the stationary wave, the oscillations of the particles at two adjacent antinodes are out of phase by 180°.

Your answer [1]

3. Stationary sound waves are produced in the air inside a tube. The tube is closed at one end.

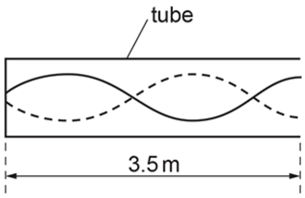
Which pattern of nodes (N) and antinodes (A) is likely to be correct?



A **B** **C** **D**

Your answer [1]

4. A stationary sound wave formed in a tube is shown below.



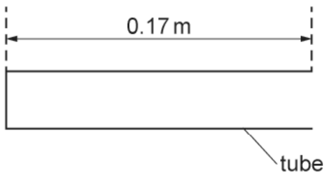
The tube is closed at one end. The length of the tube is 3.5 m.
The speed of sound is 340 m s^{-1}.

What is the frequency of the sound wave?

A 97 Hz
B 120 Hz
C 240 Hz
D 486 Hz

Your answer ☐ **[1]**

5. A stationary sound wave, of fundamental mode of vibration, is formed in a tube closed at one end.



The length of the tube is 0.17 m. The speed of sound in air is 340 m s^{-1}.

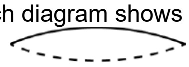
What is the fundamental frequency of the stationary wave?

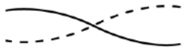
A 500 Hz
B 1000 Hz
C 2000 Hz
D 4000 Hz

Your answer ☐ **[1]**

6. A student blows across the open end of an empty bottle.

Which diagram shows a possible stationary wave pattern for this bottle?

A 

B 

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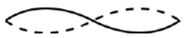
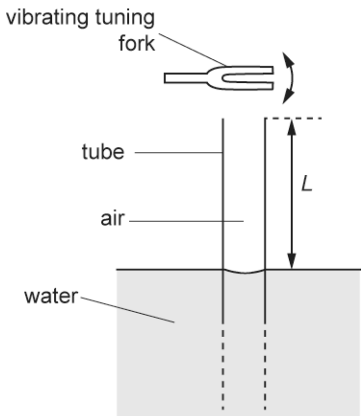
D 

Your answer ☐

[1]

7. A vibrating tuning fork is held above the open end of a long vertical tube. The other end of the tube, which is also open, is immersed in a tank of water. The length *L* of the air column within the tube is changed by raising or lowering the tube.



The wavelength of sound from the vibrating tuning fork is 150.0 cm.

What length *L* of air column will **not** produce a stationary wave within the tube?

A 37.5 cm
B 75.0 cm
C 112.5 cm
D 187.5 cm

Your answer ☐ **[1]**

8. Stationary waves are produced in a tube closed at one end and open at the other end. The fundamental frequency is 120 Hz.

What is a possible frequency of a harmonic for this tube?

A 60 Hz
B 240 Hz
C 360 Hz
D 480 Hz

Your answer ☐ **[1]**

9. The stationary wave shown below is formed on a stretched string.

The frequency of this stationary wave is 72 Hz.

What is the fundamental frequency for a stationary wave on the same string?

A 18 Hz
B 24 Hz
C 48 Hz
D 72 Hz

Your answer ☐ **[1]**

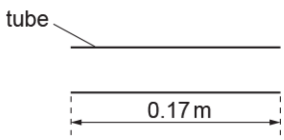
10. This question is about a progressive wave and a stationary wave.

Which statement is correct?

A A progressive wave has at least one node.
B All progressive waves are longitudinal.
C All particles oscillating between two adjacent nodes in a stationary wave are in phase.
D The superposition of two waves travelling in the same direction produces a stationary wave.

Your answer ☐ **[1]**

11. A stationary sound wave, in its fundamental mode of vibration, is formed in a tube open at both ends.



The length of the tube is 0.17 m. The speed of sound in air is 340 m s^{-1}.

Which row for this stationary wave is correct?

	Number of nodes	Frequency of stationary wave / Hz
A	1	500
B	1	1000
C	2	1000
D	2	2000

Your answer ☐ **[1]**

12. Fig. 17.1 shows the variation with distance of the displacement of a **stationary** wave at time $t = 0$.

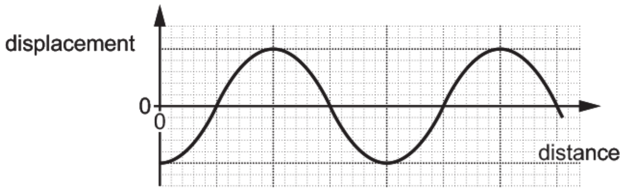


Fig. 17.1

The period of the wave is T.

i. On Fig. 17.1, sketch a graph to show the variation of the displacement at time $t = \frac{T}{2}$.

[1]

ii. On Fig. 17.1, show the positions of **all** the nodes. Label each node **N**.

[1]

13. Describe how a stationary wave is different from a progressive wave.

---

[2]

14. The speed v of the transverse waves on the string is directly proportional to $\sqrt{T}$, where T is the tension in the string.
The tension T in the string is increased by 14 %. The frequency f of the oscillator is adjusted to get the same stationary wave pattern as **Fig. 18.1**.

Calculate the percentage increase in the frequency f.

increase = ... % **[2]**

15. State **one** difference and one similarity between the **oscillations** of a stationary sound wave and a progressive sound wave

Difference: ---

Similarity: ---

[2]

16. A guitar manufacturer wants to investigate the quality of sound produced from a new uniform polymer string. **Fig. 18.1** shows the string which is kept in tension between a clamp and a pulley. The frequency of the mechanical oscillator close to one end is varied so that a stationary wave is set up on the string.

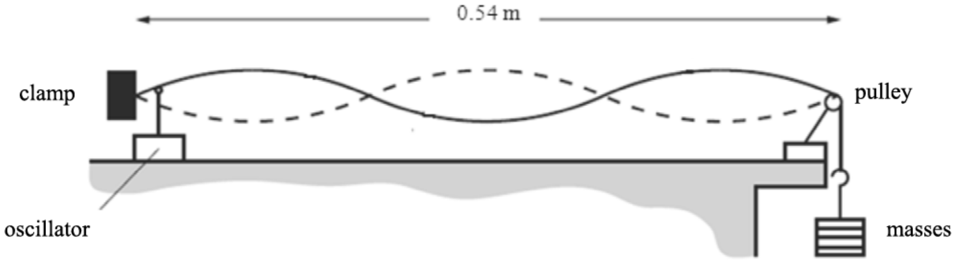


Fig. 18.1

Explain how the stationary wave is formed on this stretched string.

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[2]

17. A stretched rubber cord has its ends fixed at points **X** and **Y**. The middle of the cord is lifted vertically and then released. A stationary wave pattern with one loop is formed by the vibrating cord, see Fig. 26.2.

Fig. 26.2

i. Explain how a stationary wave pattern is produced in **this** arrangement.

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[2]

ii. The stationary wave pattern shown in Fig. 26.2 is produced in the laboratory. Describe how the wavelength of the transverse wave on the stretched cord can be determined.

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[1]

18. A guitar manufacturer wants to investigate the quality of sound produced from a new uniform polymer string. **Fig. 18.1** shows the string which is kept in tension between a clamp and a pulley. The frequency of the mechanical oscillator close to one end is varied so that a stationary wave is set up on the string.

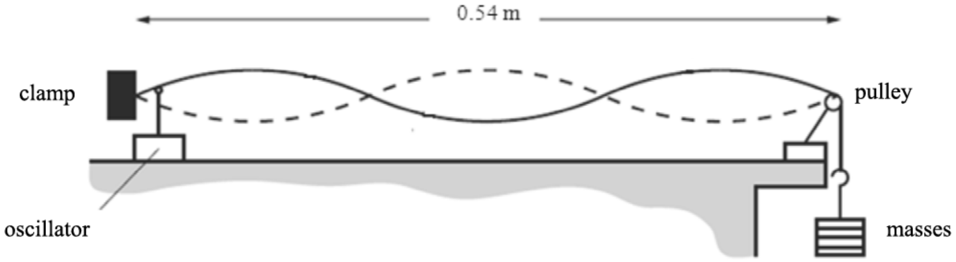

Fig. 18.1

The frequency of the oscillator is 60 Hz.

Use Fig. **18.1** to calculate the speed of the transverse waves on the string.

speed = ... m s^{-1} **[3]**

19. Stationary sound waves are formed in a tube closed at one end.
Fig. 17.2 shows three stationary wave patterns formed in the air column of the tube.

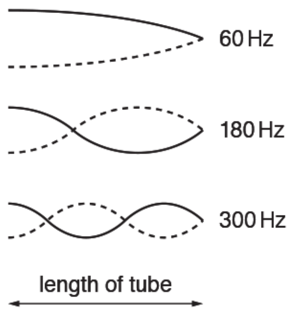

Fig. 17.2

The frequency *f* of the oscillations for each stationary wave is shown in Fig. 17.2.

Use Fig. 17.2 to explain how the frequency *f* of the sound wave depends on the wavelength *λ*.

....

....

....

....

....

[3]

20. A stretched wire of fixed length is used in an experiment to demonstrate stationary waves. The tension in the wire is kept **constant**.
Fig. 26 shows the three stationary wave patterns that can be formed on the stretched wire.

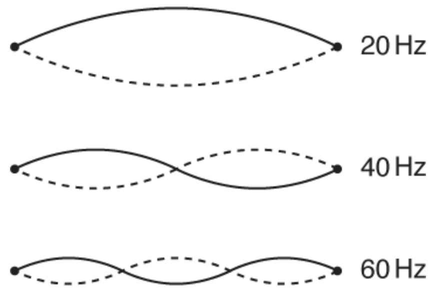

Fig. 26

The frequency *f* of vibration of the stretched wire for each stationary wave is shown on Fig. 26. Use Fig. 26 to describe and explain how the wavelength λ of the progressive wave on the stretched wire depends on the frequency of vibration of the wire.

[3]

21 (a). In an investigation of standing waves, sound waves are sent down a long pipe, with its lower end immersed in water. The waves are reflected by the water surface. The pipe is lowered until a standing wave is set up in the air in the pipe. A loud note is then heard. See **Fig. 6.1**.

Length l_1 is measured. The pipe is then lowered further until a loud sound is again obtained from the air in the pipe. Length l_2 is measured.

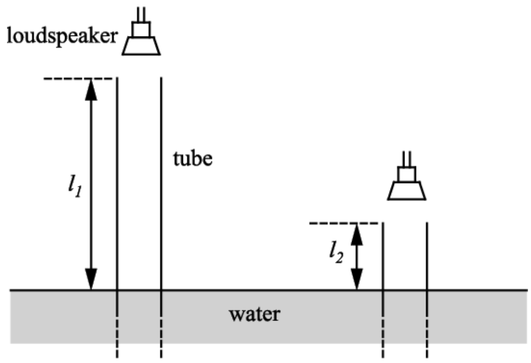

Fig 6.1

A student obtained the following results in the experiment.

frequency of sound / Hz	l_1 / m	l_2 / m
500	0.506	0.170

Use data from the table to calculate the speed of sound in the pipe.
Show your reasoning.

speed = ... m s^{-1} **[4]**

(b). The student repeats the experiment, but sets the frequency of the sound from the speaker at 5000 Hz.

Suggest and explain whether these results are likely to give a more or less accurate value for the speed of sound than those obtained in the first experiment.

-- **[2]**

(c). The pipe is removed from the water and laid horizontally on a bench as in **Fig. 6.2**. The frequency of the sound waves sent down the pipe is adjusted until a standing wave is set up in it. Point **P** is a distance of $\lambda / 4$ from point **Q** at the far end.

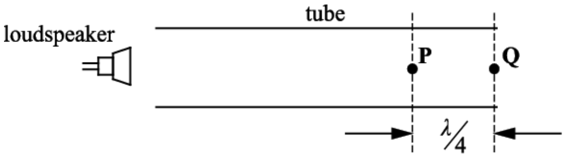

Fig. 6.2

Explain how and under what conditions a stationary sound wave is formed in the pipe. Describe and compare the motion of the air molecules at points **P** and **Q**.

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[6]

22.

In an experiment to investigate microwaves, a microwave detector **D** is placed between a microwave transmitter **T** and a flat metal sheet.

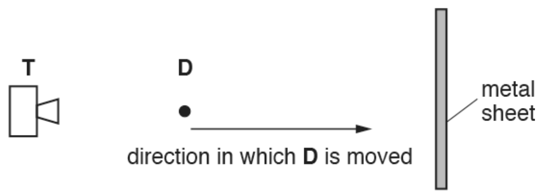

Fig. 7.1

The detected signal at **D** shows regions of maximum and minimum intensity as **D** is moved towards the metal sheet as shown in Fig. 7.1. The distance between **adjacent** regions of maximum and minimum intensities is 72mm.
Explain the presence of the regions of maximum **and** minimum intensity and determine the frequency of the microwaves.

The speed of microwaves in air is 3.0×10^8 m s^{-1}. **[6]**

23. A loudspeaker mounted on a bench is emitting sound of frequency 1.7 kHz to a microphone. Fig. 5.1 shows an illustration of the bulk movement of the air at one instant of time.

Fig. 5.1

Students are given the equipment in Fig. 5.1 together with a metre rule. They are also given a second loudspeaker connected to the same signal generator at 1.7 kHz. They are asked to design an experiment where they would need to take just **one** measurement and be able to determine the value of the speed of sound.

They set up the experiment in two different ways as shown in Fig. 5.3(a) and (b).

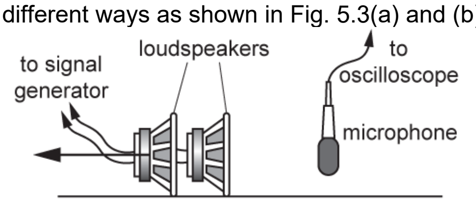

Fig. 5.3(a)

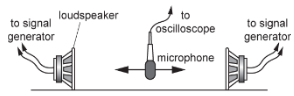

Fig. 5.3(b)

In method **(a)** the microphone is fixed and one loudspeaker is moved to the left as shown in Fig. 5.3(a).
In method **(b)** the microphone is moved to the left or to the right with the loudspeakers fixed a certain distance apart as shown in Fig. 5.3(b).

Describe and explain how both methods can be used to accurately determine the speed of sound. In your description, discuss how the uncertainty in the value for the speed of sound can be minimised in one of the methods, without using any other apparatus. **[6]**

24. A student is investigating stationary waves in a hollow tube. The tube is open at one end and closed at the other end. The student connects a signal generator to a loudspeaker which is placed just above the tube as shown in Fig. 6.

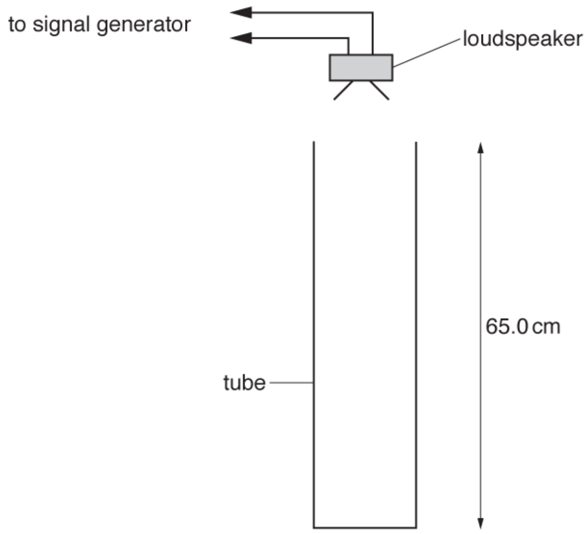

Fig. 6

The length of the tube is 65.0 cm.

As the frequency of the signal generator is slowly increased from 0 Hz the student observes sound that varies in loudness. The loudest sound occurs at frequencies 130 Hz, 390 Hz and 650 Hz.

The experiment is then repeated with a hollow tube of the **same** length but open at both ends. The loudest sound now occurs at frequencies 260 Hz, 520 Hz and 780 Hz.

Using your knowledge and understanding of stationary waves explain these observations. Include in your answer how you could determine an experimental value for the speed of sound in air.

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[6]

25. *Fig. 18.2 shows an arrangement used to investigate **stationary** sound waves in a tube closed at one end.

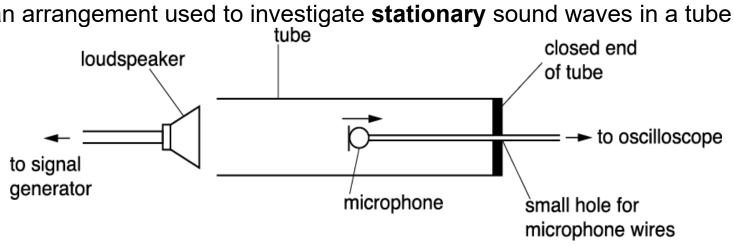

Fig. 18.2

A loudspeaker is placed at the open end of the tube. The loudspeaker emits sound of constant frequency. A small microphone is placed inside the tube. The microphone is connected to an oscilloscope. The microphone is slowly moved from the open end of the tube towards its closed end. The signal detected by the microphone shows regions of maximum and minimum intensity of sound. The distance between adjacent positions of maximum signal is 0.26 m.

Fig. 18.3 shows the signal displayed on the oscilloscope when the output signal from the microphone is maximum. The time-base on the oscilloscope is set at 0.50 ms div^{-1}.

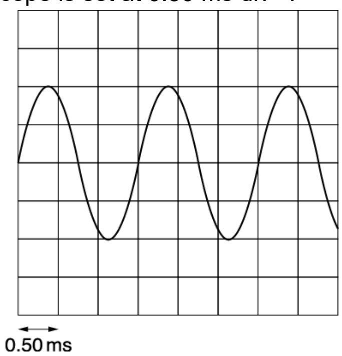

Fig. 18.3

Explain the presence of the regions of maximum and minimum intensities of sound within the tube and determine the speed of sound.

[6]

26 (a). Fig. 5.1 shows a horizontal copper wire placed between the opposite poles of a permanent magnet. The wire is held in tension *T* by the clamps at each end. The length of the wire in the magnetic field of flux density 0.032 tesla is 6.0 cm.

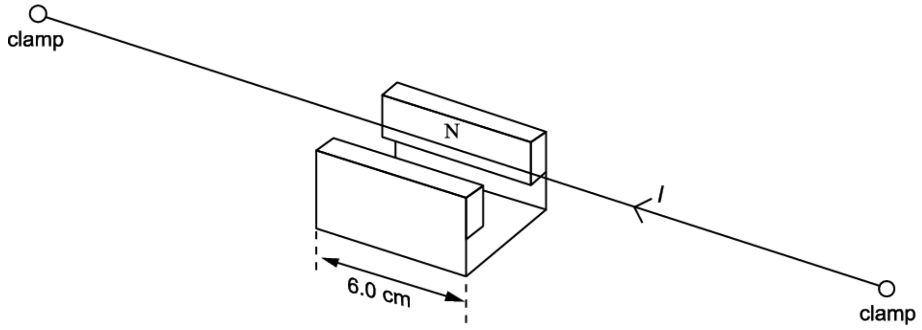

Fig. 5.1

The direct current is changed to an alternating current of constant amplitude and variable frequency, causing the wire to oscillate. The frequency of the current is increased until the fundamental natural frequency of the wire is found as shown in Fig. 5.2. This is 70 Hz.

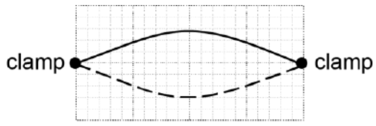

Fig. 5.2

i. In the situation shown in Fig. 5.2 the amplitude of the oscillation of the centre point of the wire is 4.0 mm. Calculate the maximum acceleration of the wire at this point.

maximum acceleration = ... m s^{-2} **[2]**

ii. The frequency is increased until another stationary wave pattern occurs. The amplitude of this stationary wave is much smaller.

1. Sketch this pattern on Fig. 5.3 and state the frequency

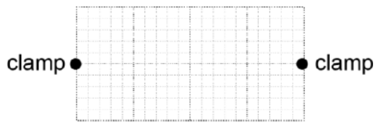

Fig. 5.3

frequency = ... Hz **[1]**

2. Explain why the amplitude is so small. Suggest how the experiment can be modified to increase the amplitude.

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[3]

(b). The speed *v* of a transverse wave along the wire is given by $v = \sqrt{\frac{T}{\mu}}$, where *T* is the tension and μ is the mass per unit length of the wire.

i. Assume that both the length and mass per unit length remain constant when the tension in the wire is halved.
Calculate the frequency of the new fundamental mode of vibration of the wire.

frequency = ... Hz **[1]**

ii. In practice the mass per unit length changes because the wire contracts when the tension is reduced. For the situation in which the tension is halved the strain reduction is found to be 0.4%.

1. Calculate the percentage change in *μ.* State both the size and sign of the change.

percentage change in *μ* = ... % **[1]**

2. Write down the percentage error this causes in your answer to **(i)**. State, giving your reasoning, whether the actual frequency would be higher or lower than your value.

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[2]

27. The speed of sound in air can be determined by forming stationary waves in the laboratory. Fig. 24.1 shows an arrangement used by a student to determine the speed of sound v.

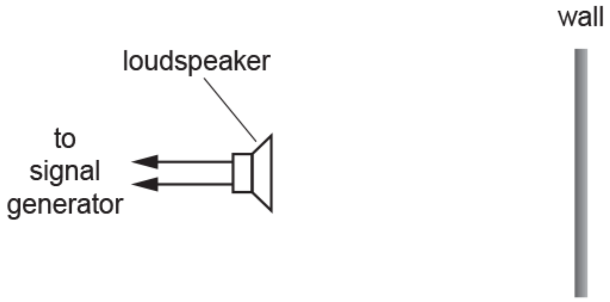

Fig. 24.1

A loudspeaker is placed in front of a smooth vertical wall in the laboratory. The loudspeaker is connected to a signal generator.
Stationary waves of frequency f are formed in the space between the wall and the loudspeaker.

A microphone is used to determine the mean separation L between adjacent nodes.

Fig. 24.2 shows the data plotted by the student.

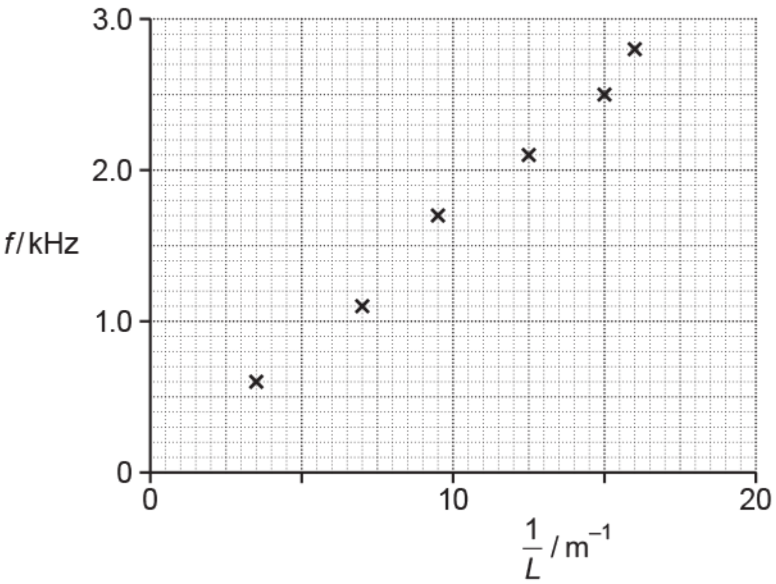

Fig. 24.2

i. Draw a straight line of best fit and determine the gradient of this line.

gradient = ... Hzm **[2]**

ii. Explain why the gradient of the line is $\frac{v}{2}$, where v is the speed of sound.

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[2]

iii. Use your answer in part **(i)** and the information given in **(ii)** to determine *v*.

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

iv. The smaller values of *L* are much more difficult to determine with the microphone in this experiment and this produces large percentage uncertainty in the values of $\frac{1}{L}$.
Suggest how this percentage uncertainty may be reduced in this experiment.

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[2]

28. * A student carries out two investigations with these electromagnetic waves.

In **investigation 1**, the student rotates the receiver aerial about the horizontal axis joining the two aerials, as shown in **Fig. 5.1**.

In **investigation 2**, the student places a metal sheet behind the receiver aerial. The student moves the sheet backwards and forwards along the horizontal axis joining the two aerials, as shown in **Fig. 5.2**.

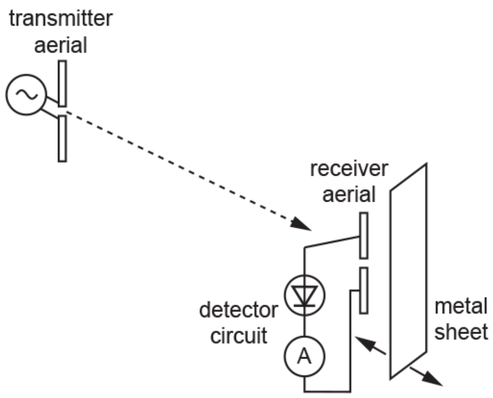

Fig. 5.2

For each of these two investigations:

- Explain why the ammeter sometimes gives a maximum reading and sometimes a zero (or near zero) reading.
- State the orientations of the receiver aerial in **investigation 1**, and the positions of the metal sheet in **investigation 2**, where these maximum and zero readings would occur.

---

[6]

29. Some students are asked to use the laboratory 28 mm microwave transmitter **T** and receiver **R** apparatus to design a demonstration to illustrate the principle of a radar speed measuring device.

In **Fig. 3.1**, a movable hardboard sheet **H**, which is a partial reflector of microwaves, is placed in front of the metal sheet **M**, which is fixed.

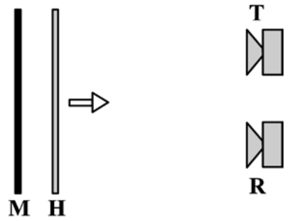

Fig. 3.1

The students expect the detected signal to change between maximum and minimum intensity when sheet **H** moves a distance of 7 mm towards the receiver.

When the detected signal is passed through an audio amplifier to a loudspeaker a sound should be heard. They claim that when the sheet moves at 2.8 m s^{-1} the frequency heard should be 200 Hz. You are to evaluate whether their experiment is feasible and whether their conclusions are correct.

i. Explain why the detected signal strength should vary and discuss what factors will determine whether the difference between maxima and minima can be detected.

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[6]

ii. Justify the students' predictions of 7 mm between maxima and minima and a sound at 200 Hz for a speed of 2.8 m s^{-1}.

[3]

END OF QUESTION PAPER