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Stationary waves: 15

TOPIC- Formation, determining wavelength and speed of sound

01 **(a)** A progressive wave transfers energy. A stationary wave does not transfer energy. State two other differences between progressive waves and stationary waves.

1. ....

....

2. ....

.... [2]

(b) A stationary wave is formed on a stretched string between two fixed points A and B. The variation of the displacement y of particles of the string with distance x along the string for the wave at time t = 0 is shown on Fig. 5.1.

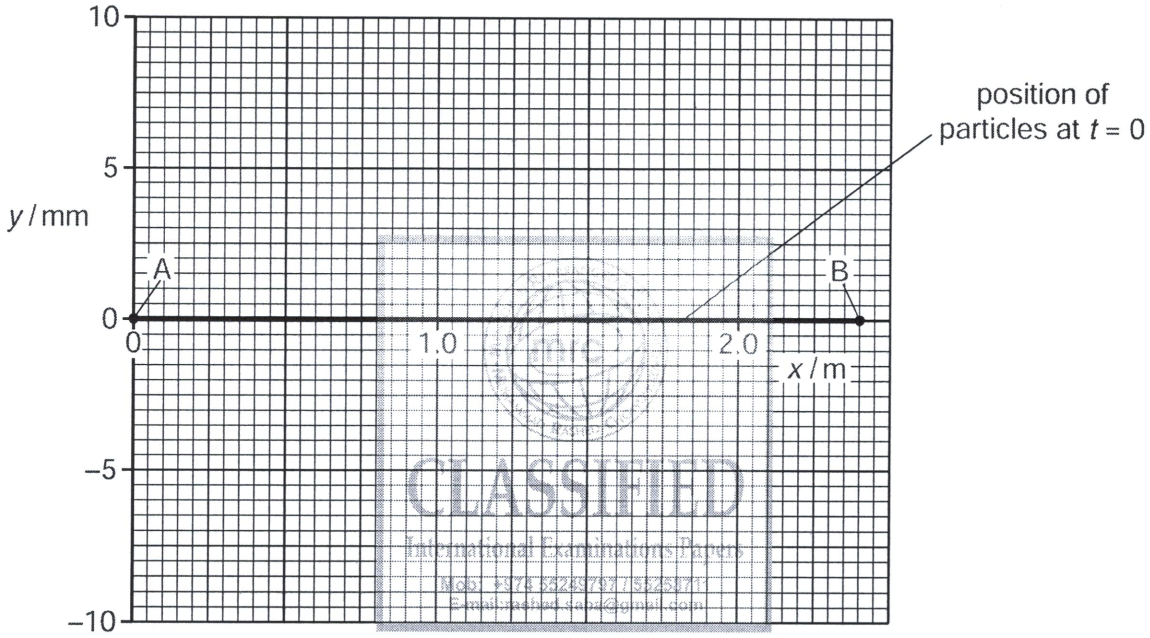

Fig. 5.1

The wave has a period of 20 ms and a wavelength of 1.2 m. The maximum amplitude of the particles of the string is 5.0 mm.

(i) On Fig. 5.1, draw a line to represent the position of the string at t = 5.0 ms. [2]

(ii) State the phase difference between the particles of the string at x = 0.40 m and at x = 0.80 m.

phase difference = ... unit .... [1]

(iii) State and explain the change in the kinetic energy of a particle at an antinode between t = 0 and t = 5.0 ms. A numerical value is not required.

....

....

....

.... [2]

02 **(a)** Use the principle of superposition to explain the formation of a stationary wave.

....

....

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....

.... [3]

For Examiner's Use

(b) Describe an experiment to determine the wavelength of sound in air using stationary waves. Include a diagram of the apparatus in your answer.

....

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....

.... [3]

(c) The variation with distance x of the intensity I of a stationary sound wave is shown in Fig. 6.1.

For Examiner's Use

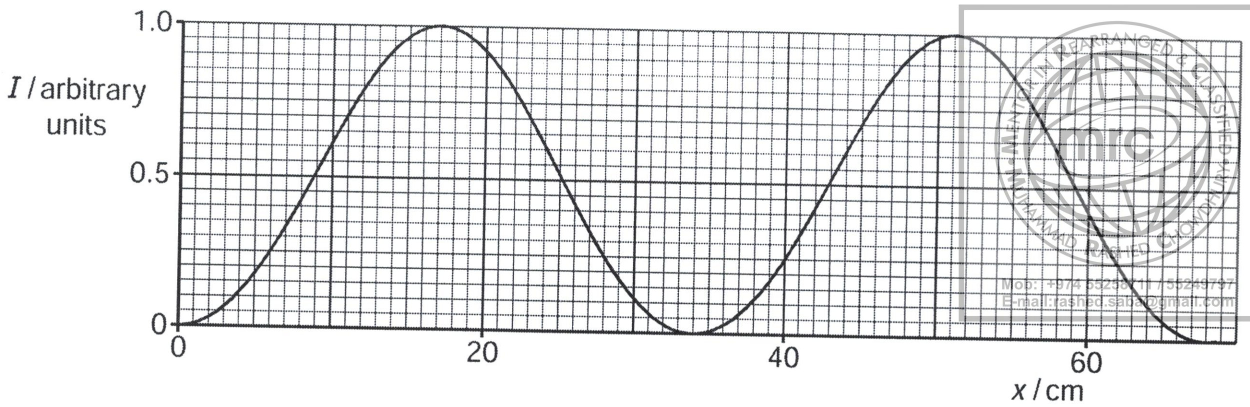

Fig. 6.1

(i) On the x-axis of Fig. 6.1, indicate the positions of all the nodes and antinodes of the stationary wave. Label the nodes **N** and the antinodes **A**. [1]

(ii) The speed of sound in air is $340\,\text{m}\,\text{s}^{-1}$.

Use Fig. 6.1 to determine the frequency of the sound wave.

frequency = ... Hz [3]

Please turn over for Question 7.

0 3 A uniform string is held between a fixed point P and a variable-frequency oscillator, as shown in Fig. 5.1.

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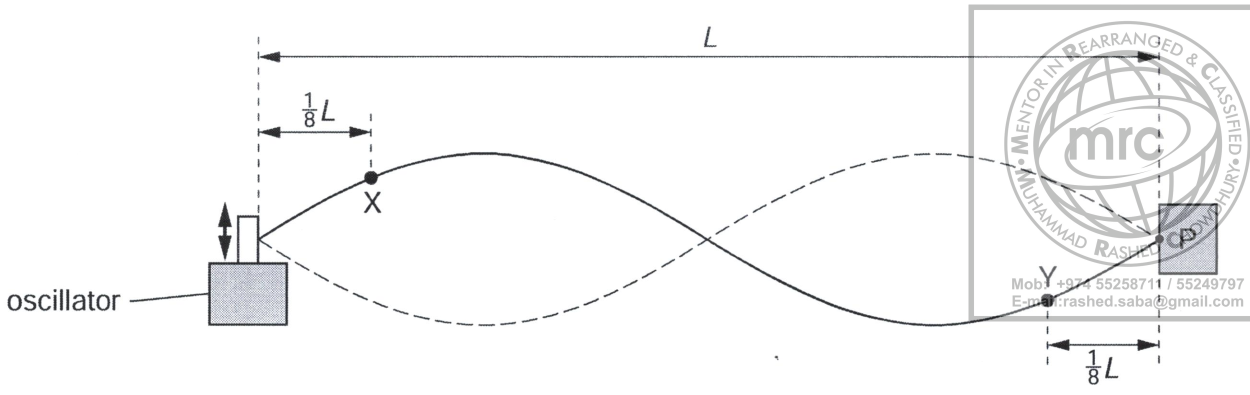

Fig. 5.1

The distance between point P and the oscillator is L.

The frequency of the oscillator is adjusted so that the stationary wave shown in Fig. 5.1 is formed.

Points X and Y are two points on the string.

Point X is a distance $\frac{1}{8}L$ from the end of the string attached to the oscillator. It vibrates with frequency f and amplitude A.

Point Y is a distance $\frac{1}{8}L$ from the end P of the string.

(a) For the vibrations of point Y, state

(i) the frequency (in terms of f),

frequency = ... [1]

(ii) the amplitude (in terms of A).

amplitude = ... [1]

(b) State the phase difference between the vibrations of point X and point Y.

phase difference = ... [1]

(c) **(i)** State, in terms of *f* and *L*, the speed of the wave on the string.

speed = ... [1]

For Examiner's Use

(ii) The wave on the string is a stationary wave.

Explain, by reference to the formation of a stationary wave, what is meant by the speed stated in **(i)**.

....

....

....

....

.... [3]

0 4 A string is stretched between two fixed points. It is plucked at its centre and the string vibrates, forming a stationary wave as illustrated in Fig. 4.1.

For Examiner's Use

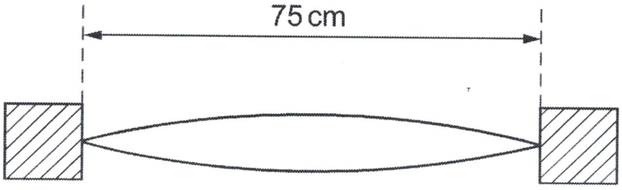

Fig. 4.1

The length of the string is 75 cm.

(a) State the wavelength of the wave.

wavelength = ... m [1]

(b) The frequency of vibration of the string is 360 Hz. Calculate the speed of the wave on the string.

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

(c) By reference to the formation of the stationary wave on the string, explain what is meant by the speed calculated in **(b)**.

....

....

.... [3]

05 **(a)** State what is meant by

For Examiner's Use

(i) the *frequency* of a progressive wave,

....

....

.... [2]

(ii) the *speed* of a progressive wave.

....

.... [1]

(b) One end of a long string is attached to an oscillator. The string passes over a frictionless pulley and is kept taut by means of a weight, as shown in Fig. 5.1.

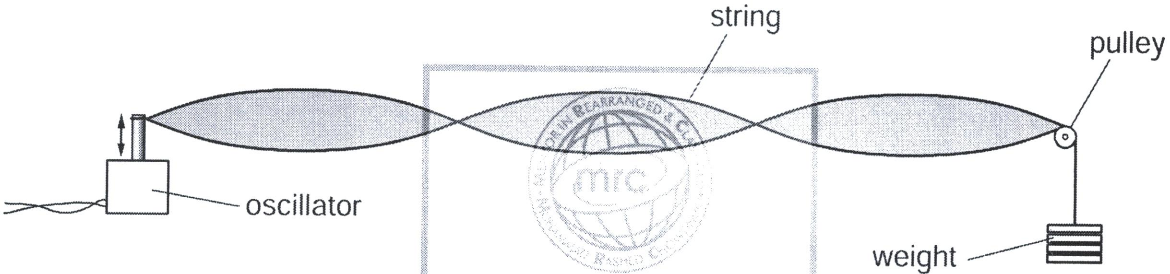

Fig. 5.1

The frequency of oscillation is varied and, at one value of frequency, the wave formed on the string is as shown in Fig. 5.1.

(i) Explain why the wave is said to be a *stationary wave*.

....

.... [1]

(ii) State what is meant by an *antinode*.

....

.... [1]

(iii) On Fig. 5.1, label the antinodes with the letter A. [1]

(c) A weight of 4.00 N is hung from the string in **(b)** and the frequency of oscillation is adjusted until a stationary wave is formed on the string. The separation of the antinodes on the string is 17.8 cm for a frequency of 125 Hz.
The speed v of waves on a string is given by the expression

$$v = \sqrt{\frac{T}{m}},$$

where T is the tension in the string and m is its mass per unit length.
Determine the mass per unit length of the string.

mass per unit length = ... $kg\,m^{-1}$ [5]

06 (a) State two differences between progressive waves and stationary waves.

1. ....

....

2. ....

.... [2]

(b) A source S of microwaves is placed in front of a metal reflector R, as shown in Fig. 6.1.

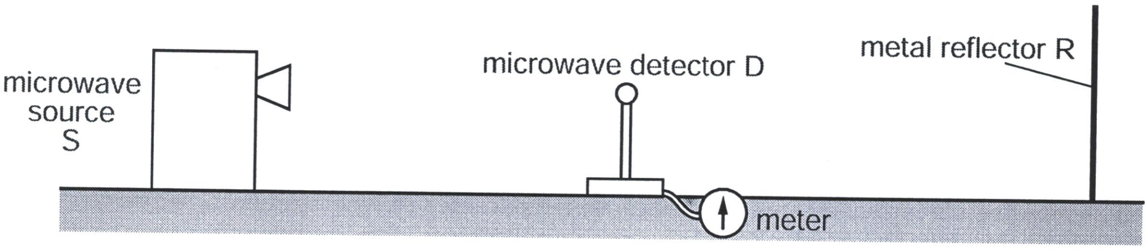

Fig. 6.1

A microwave detector D is placed between R and S.

Describe

(i) how stationary waves are formed between R and S,

....

....

....

.... [3]

(ii) how D is used to show that stationary waves are formed between R and S,

....

....

.... [2]

(iii) how the wavelength of the microwaves may be determined using the apparatus in Fig. 6.1.

....

....

.... [2]

(c) The wavelength of the microwaves in **(b)** is 2.8 cm. Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [3]

Please turn over for Question 7.

07 (a) Apparatus used to produce stationary waves on a stretched string is shown in Fig. 7.1.

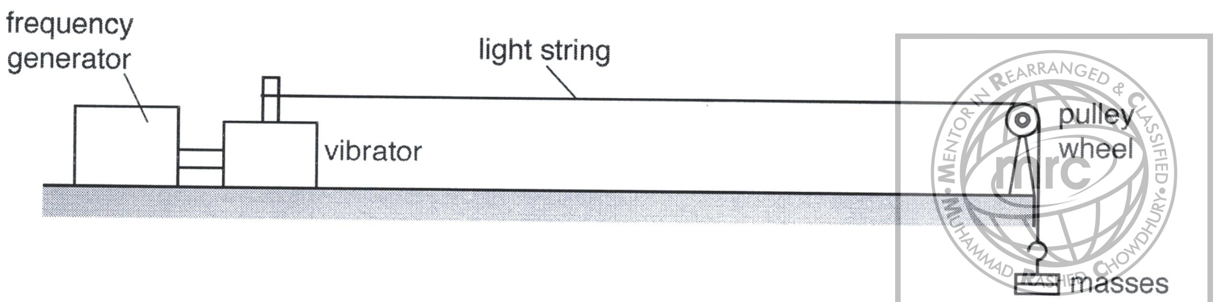

Fig. 7.1

The frequency generator is switched on.

(i) Describe two adjustments that can be made to the apparatus to produce stationary waves on the string.

1. ....

....

2. ....

.... [2]

(ii) Describe the features that are seen on the stretched string that indicate stationary waves have been produced.

.... [1]

(b) The variation with time *t* of the displacement *x* of a particle caused by a progressive wave R is shown in Fig. 7.2. For the same particle, the variation with time *t* of the displacement *x* caused by a second wave S is also shown in Fig. 7.2.

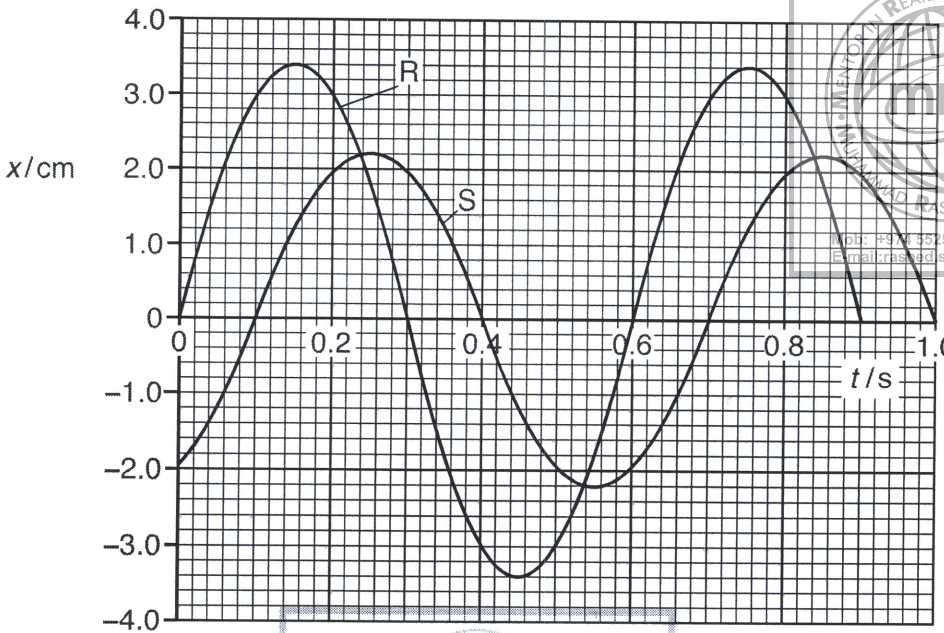

Fig. 7.2

(i) Determine the phase difference between wave R and wave S. Include an appropriate unit.

phase difference = ... [1]

(ii) Calculate the ratio

$$\frac{\text{intensity of wave R}}{\text{intensity of wave S}}.$$

ratio = ... [2]

[Total: 6]

08 Fig. 5.1 shows a string stretched between two fixed points P and Q.

For Examiner's Use

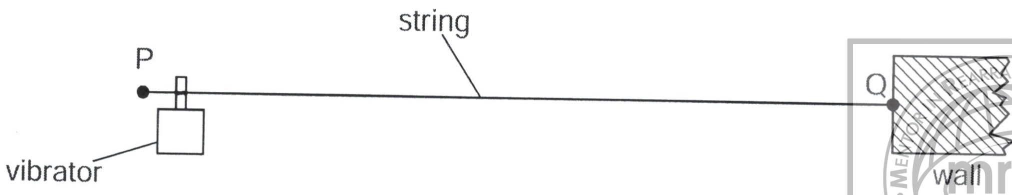

Fig. 5.1

A vibrator is attached near end P of the string. End Q is fixed to a wall. The vibrator has a frequency of 50 Hz and causes a transverse wave to travel along the string at a speed of $40\,m\,s^{-1}$.

(a) **(i)** Calculate the wavelength of the transverse wave on the string.

wavelength = ... m [2]

(ii) Explain how this arrangement may produce a stationary wave on the string.

....

....

.... [2]

(b) The stationary wave produced on PQ at one instant of time t is shown on Fig. 5.2. Each point on the string is at its maximum displacement.

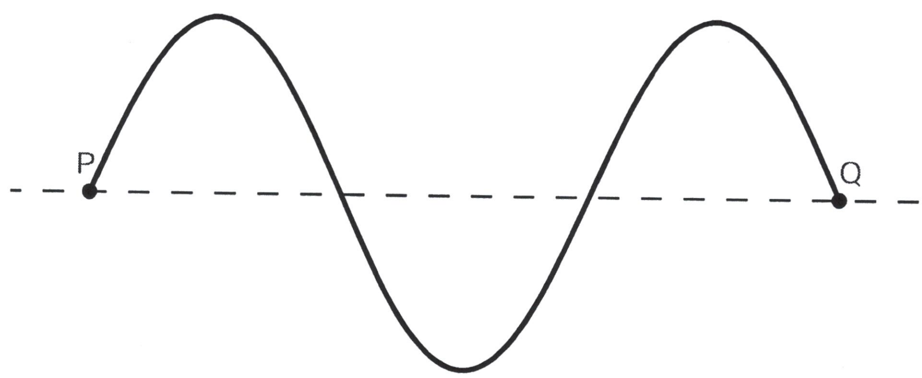

Fig. 5.2 (not to scale)

(i) On Fig. 5.2, label all the nodes with the letter **N** and all the antinodes with the letter **A**. [2]

(ii) Use your answer in **(a)(i)** to calculate the length of string PQ.

For Examiner's Use

length = ... m [1]

(iii) On Fig. 5.2, draw the stationary wave at time (t + 5.0 ms). Explain your answer.

.... [3]

09 Fig. 4.1 shows an arrangement for producing stationary waves in a tube that is closed at one end.

For Examiner's Use

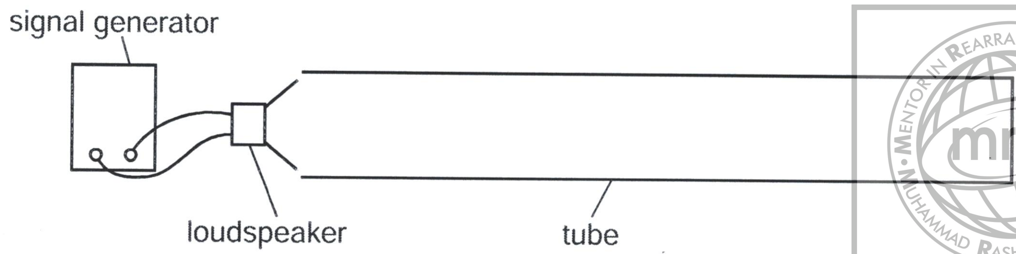

Fig. 4.1

(a) Explain how waves from the loudspeaker produce stationary waves in the tube.

....

....

....

....

....[3]

(b) One of the stationary waves that may be formed in the tube is represented in Fig. 4.2.

Fig. 4.2

(i) Describe the motion of the air particles in the tube at

1. point P,

....[1]

2. point S.

....[1]

(ii) The speed of sound in the tube is $330\,m\,s^{-1}$ and the frequency of the waves from the loudspeaker is 880 Hz. Calculate the length of the tube.

length = ... m [3]

10 **(a)** State two features of a stationary wave that distinguish it from a progressive wave.

For Examiner's Use

1. ....

....

2. ....

.... [2]

(b) A long tube is open at one end. It is closed at the other end by means of a piston that can be moved along the tube, as shown in Fig. 4.1.

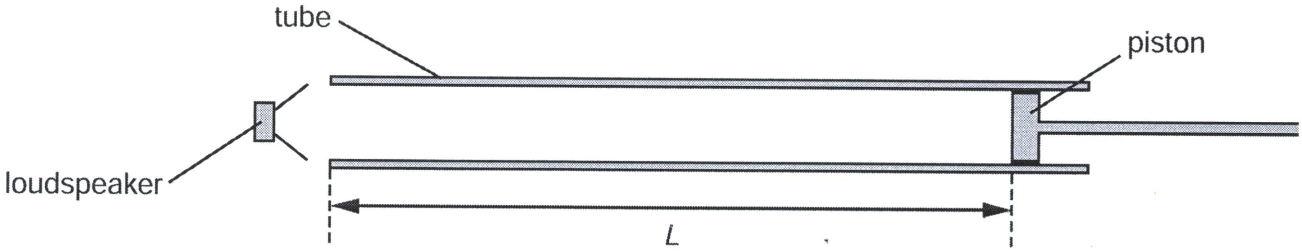

Fig. 4.1

A loudspeaker producing sound of frequency 550 Hz is held near the open end of the tube.
The piston is moved along the tube and a loud sound is heard when the distance L between the piston and the open end of the tube is 45 cm.
The speed of sound in the tube is $330\,\mathrm{m\,s^{-1}}$.

(i) Show that the wavelength of the sound in the tube is 60 cm.

[1]

(ii) On Fig. 4.1, mark all the positions along the tube of

1. the displacement nodes (label these with the letter N),

2. the displacement antinodes (label these with the letter A).

[3]

(c) The frequency of the sound produced by the loudspeaker in **(b)** is gradually reduced.

For Examiner's Use

Determine the lowest frequency at which a loud sound will be produced in the tube of length L = 45 cm.

frequency = ... Hz [3]

11 A hollow tube is used to investigate stationary waves. The tube is closed at one end and open at the other end. A loudspeaker connected to a signal generator is placed near the open end of the tube, as shown in Fig. 6.1.

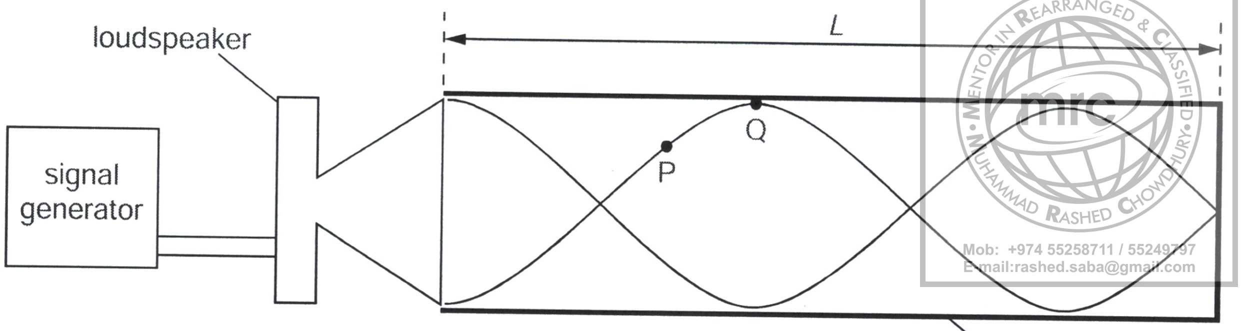

Fig. 6.1

The tube has length L. The frequency of the signal generator is adjusted so that the loudspeaker produces a progressive wave of frequency 440 Hz. A stationary wave is formed in the tube. A representation of this stationary wave is shown in Fig. 6.1.
Two points P and Q on the stationary wave are labelled.

(a) **(i)** Describe, in terms of energy transfer, the difference between a progressive wave and a stationary wave.

....

.... [1]

(ii) Explain how the stationary wave is formed in the tube.

....

....

....

.... [3]

(iii) State the direction of the oscillations of an air particle at point P.

....

.... [1]

(b) On Fig. 6.1 label, with the letter N, the nodes of the stationary wave. [1]

(c) State the phase difference between points P and Q on the stationary wave.

phase difference = ... [1]

(d) The speed of sound in the tube is $330\,m\,s^{-1}$.

Calculate

(i) the wavelength of the sound wave,

wavelength = ... m [2]

(ii) the length L of the tube.

length = ... m [2]

12 (a) State the conditions required for the formation of stationary waves.

....

....

.... [2]

(b) One end of a string is attached to a vibrator. The string is stretched by passing the other end over a pulley and attaching a load, as illustrated in Fig. 4.1.

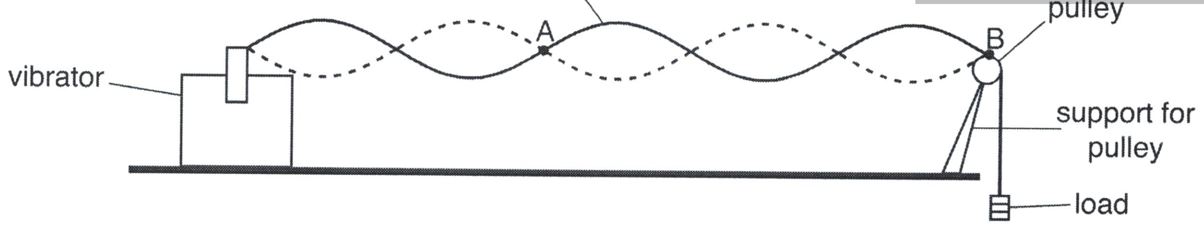

Fig. 4.1

The frequency of vibration of the vibrator is adjusted to 250 Hz and a transverse wave travels along the string with a speed of $12\,\text{m}\,\text{s}^{-1}$. The wave is reflected at the pulley and a stationary wave forms on the string.

Fig. 4.2 shows the string between points A and B at time $t = t_1$.

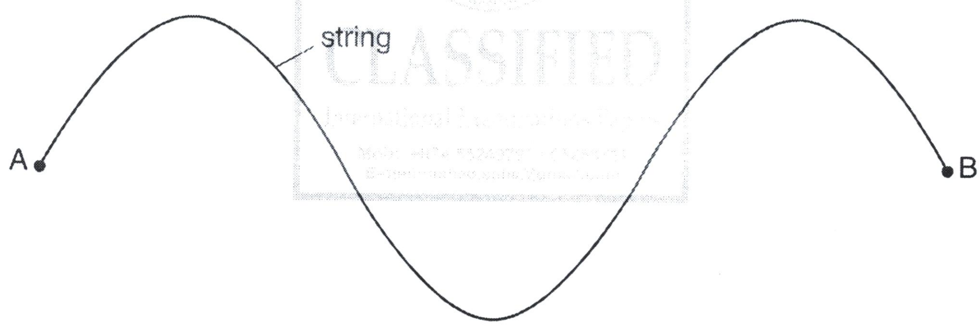

Fig. 4.2

At time $t = t_1$ the string has maximum displacement.

(i) Calculate the distance AB.

distance = ... m [2]

(ii) On Fig. 4.2, sketch the position of the string between A and B at times

1. $t = t_1 + 2.0\,\text{ms}$ (label this line P),

2. $t = t_1 + 5.0\,\text{ms}$ (label this line Q).

[3]

[Total: 7]

For Examiner's Use

13 A long tube, fitted with a tap, is filled with water. A tuning fork is sounded above the top of the tube as the water is allowed to run out of the tube, as shown in Fig. 6.1.

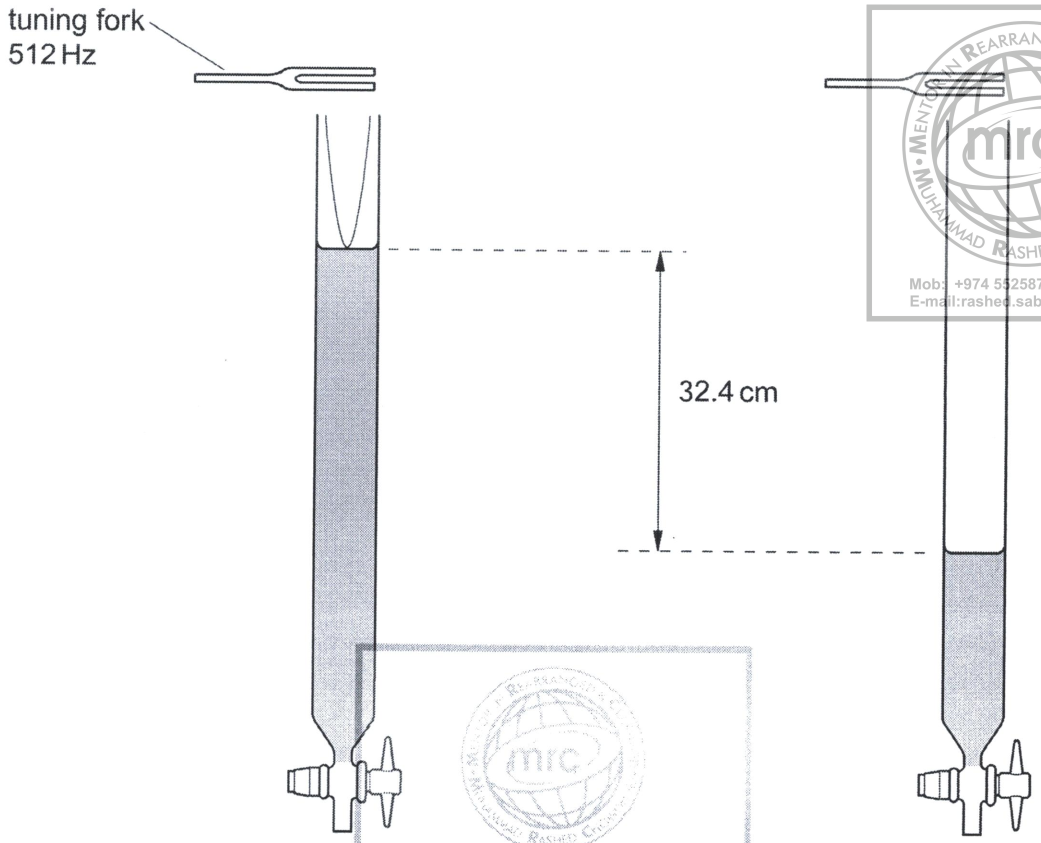

Fig. 6.1 **Fig. 6.2**

A loud sound is first heard when the water level is as shown in Fig. 6.1, and then again when the water level is as shown in Fig. 6.2.

Fig. 6.1 illustrates the stationary wave produced in the tube.

(a) On Fig. 6.2,

(i) sketch the form of the stationary wave set up in the tube, [1]

(ii) mark, with the letter N, the positions of any nodes of the stationary wave. [1]

(b) The frequency of the fork is 512 Hz and the difference in the height of the water level for the two positions where a loud sound is heard is 32.4 cm.

Calculate the speed of sound in the tube.

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

(c) The length of the column of air in the tube in Fig. 6.1 is 15.7 cm.

Suggest where the antinode of the stationary wave produced in the tube in Fig. 6.1 is likely to be found.

....

....

.... [2]

14 Light reflected from the surface of smooth water may be described as a polarised transverse wave.

(a) By reference to the direction of propagation of energy, explain what is meant by

(i) a *transverse wave*,

....

....[1]

(ii) *polarisation*.

....

....[1]

(b) A glass tube, closed at one end, has fine dust sprinkled along its length. A sound source is placed near the open end of the tube, as shown in Fig. 5.1.

Fig. 5.1

The frequency of the sound emitted by the source is varied and, at one frequency, the dust forms small heaps in the tube.

(i) Explain, by reference to the properties of stationary waves, why the heaps of dust are formed.

....

....

....

....[3]

(ii) One frequency at which heaps are formed is 2.14 kHz.
The distance between six heaps, as shown in Fig. 5.1, is 39.0 cm.
Calculate the speed of sound in the tube.

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

(c) The wave in the tube is a stationary wave. Explain, by reference to the formation of a stationary wave, what is meant by the speed calculated in **(b)(ii)**.

....

....

....

.... [3]