8. Superposition

8.1 Stationary waves

Paper 2

Question Paper

1 A stretched string PQ has length 1.2 m. One end of the string is attached to a vibration generator and the other end is attached to a wall, as shown in Fig. 5.1.

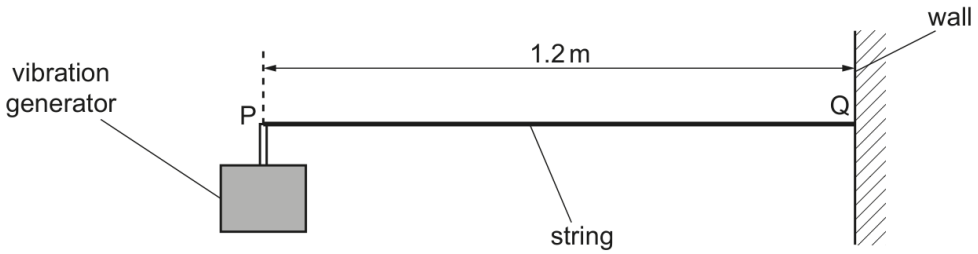


Fig. 5.1

The vibration generator is switched on and a stationary wave is formed on the string. The string is shown at one instant of time in Fig. 5.2.



Fig. 5.2

(a) Explain how a stationary wave is formed between the vibration generator and the wall.

.....

.....

.....

..... [2]

(b) Calculate the wavelength of the stationary wave shown in Fig. 5.2.

wavelength = ... m [1]

(c) Fig. 5.3 shows the stationary wave at time $t = 0$ when all points on the wave are at their maximum displacements.

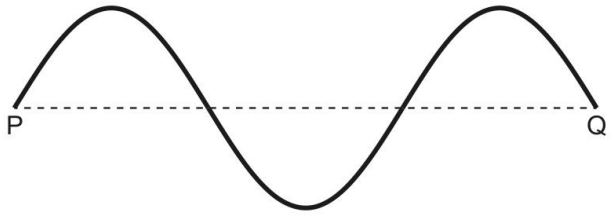


Fig. 5.3

The period of the wave is 0.16 s.

On Fig. 5.3, sketch the shape of the stationary wave at time $t = 0.24$ s. [2]

(d) Points R and T on the string are a horizontal distance of 0.30 m apart and in the positions shown in Fig. 5.4.

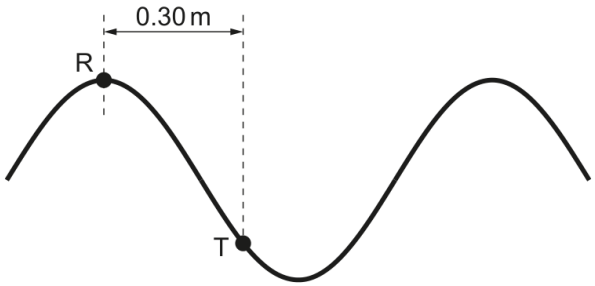


Fig. 5.4

State the phase difference between the oscillations of points R and T.

phase difference = ... ° [1]

2 **(b)** A pipe is open at one end and closed at the other with a piston. The piston can slide freely and is at a distance of 4.5×10^{-2} m from the open end of the pipe.

A loudspeaker is positioned near the open end of the pipe and emits a sound wave of a single constant frequency. A stationary wave is formed in the pipe, as illustrated in Fig. 4.1.

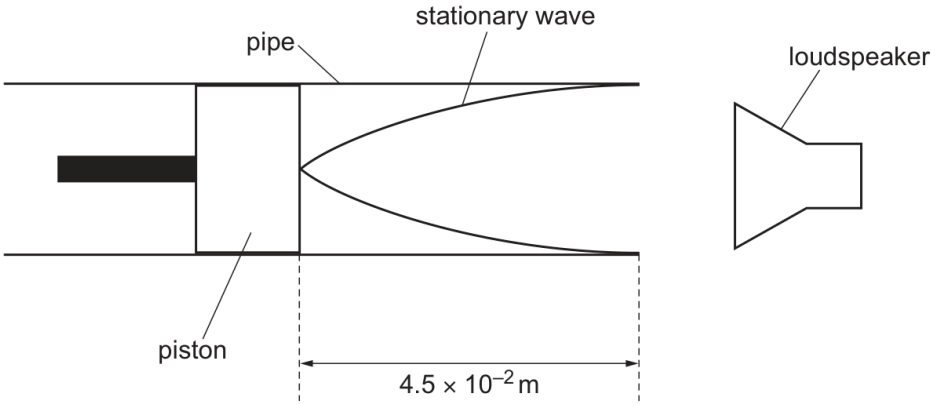


Fig. 4.1

(i) On Fig. 4.1, draw a letter A at the position of an antinode. [1]

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

Determine the frequency of the sound wave.

frequency = ... Hz [3]

(iii) The piston is moved to the left. The frequency of the sound wave emitted by the loudspeaker is then changed so that a stationary wave is formed with same number of antinodes as in Fig. 4.1.

State and explain the change that is made to the frequency of the sound wave.

.....

.....

.....

..... [2]

3 **(b)** A tube is closed at one end. A loudspeaker is placed near the other end of the tube, as shown in Fig. 5.1.

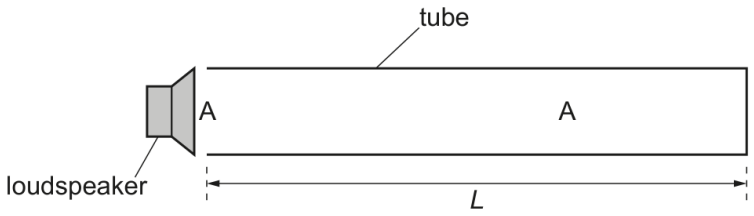


Fig. 5.1 (not to scale)

The loudspeaker emits sound of frequency 1.7 kHz. The speed of sound in the air in the tube is 340 m s^{-1}. A stationary wave is formed with an antinode A at the open end of the tube. There is only one other antinode A inside the tube, as shown in Fig. 5.1.

Determine:

(ii) the length *L* of the tube

L = ... m [1]

(iii) the maximum wavelength of the sound from the loudspeaker that can produce a stationary wave in the tube.

maximum wavelength = ... m [1]

4 **(a)** State the principle of superposition.

.....

.....

..... [2]

5 A horizontal string is stretched between two fixed points A and B. A vibrator is used to oscillate the string and produce an observable stationary wave.

At one instant, the moving string is straight, as shown in Fig. 5.1.



Fig. 5.1

The dots in the diagram represent the positions of the nodes on the string. Point P on the string is moving downwards.

The wave on the string has a speed of $35\,m\,s^{-1}$ and a period of $0.040\,s$.

(a) Explain how the stationary wave is formed on the string.

.....

.....

.....

..... [2]

(b) On Fig. 5.1, sketch a line to show a possible position of the string a quarter of a cycle later than the position shown in the diagram. [1]

(c) Determine the horizontal distance from A to B.

distance = ... m [3]

6 **(c)** A microwave of intensity I_0 and amplitude A_0 meets another microwave of the same frequency and of intensity $\frac{1}{4}I_0$ travelling in the opposite direction. Both microwaves are vertically plane polarised and superpose where they meet.

(i) Explain, without calculation, why these two waves cannot form a stationary wave with zero amplitude at its nodes.

.....

.....

..... [2]

7 **(a)** Two progressive sound waves meet to form a stationary wave. The two waves have the same amplitude, wavelength, frequency and speed.

State the other condition that must be fulfilled by the two waves in order for them to produce the stationary wave.

..... [1]

(b) A stationary wave is formed on a string that is stretched between two fixed points A and B. Fig. 5.1 shows the string at time $t = 0$ when each point is at its maximum displacement.

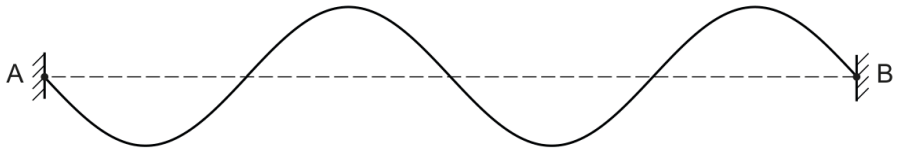


Fig. 5.1

Distance AB is 0.80 m. The period of the stationary wave is 0.016 s.

(i) On Fig. 5.1, sketch a solid line to show the position of the string:

- at time $t = 0.004$ s (label this line P)
- at time $t = 0.024$ s (label this line Q).

[2]

(ii) Determine the speed of a progressive wave along the string.

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

8 A tube is initially fully submerged in water. The axis of the tube is kept vertical as the tube is slowly raised out of the water, as shown in Fig. 5.1.

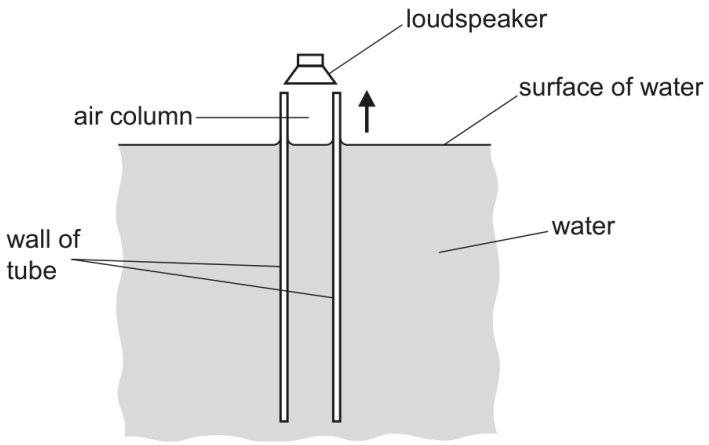


Fig. 5.1

A loudspeaker producing sound of frequency 530 Hz is positioned at the open top end of the tube as it is raised. The water surface inside the tube is always level with the water surface outside the tube. The speed of the sound in the air column in the tube is 340 m s^{-1}.

(a) Describe a simple way that a student, without requiring any additional equipment, can detect when a stationary wave is formed in the air column as the tube is being raised.

.....

..... [1]

(b) Determine the height of the top end of the tube above the surface of the water when a stationary wave is first produced in the tube. Assume that an antinode is formed level with the top of the tube.

height = ... m [3]

(c) Determine the distance moved by the tube between the positions at which the first and second stationary waves are formed.

distance = ... m [1]

9 **(a)** **(ii)** State the principle of superposition.

.....

.....

..... [2]

10 **(c)** A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

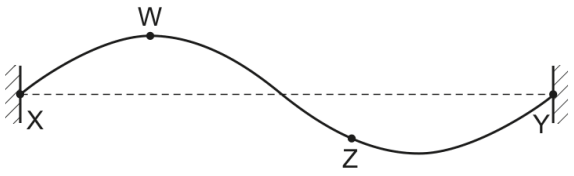


Fig. 4.2

(i) Explain what is meant by a *node* of a stationary wave.

..... [1]

(ii) State the number of antinodes of the wave shown in Fig. 4.2.

number = ... [1]

(iii) State the phase difference between points W and Z on the string.

phase difference = ...° [1]

(iv) A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.



Fig. 4.3

[1]

11 **(a)** Describe the conditions required for two waves to be able to form a stationary wave.

.....

.....

.....

..... [2]

(b) A stationary wave on a string has nodes and antinodes. The distance between a node and an adjacent antinode is 6.0 cm.

(i) State what is meant by a *node*.

..... [1]

(ii) Calculate the wavelength of the two waves forming the stationary wave.

wavelength = ... cm [1]

(iii) State the phase difference between the particles at two adjacent antinodes of the stationary wave.

phase difference = ... ° [1]

12 (b) Fig. 4.1 shows the variation with time t of the displacement x of two progressive waves P and Q passing the same point.

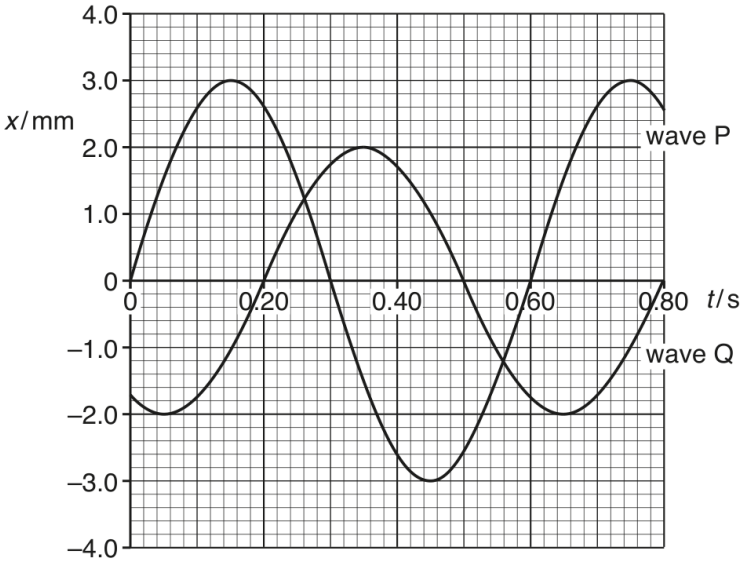


Fig. 4.1

The speed of the waves is 20 cm s^{-1}.

(iv) The two waves superpose as they pass the same point. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.45$ s.

displacement = ... mm [1]

13 (a) (ii) State what is meant by an *antinode* of a stationary wave.

.....

.....[1]

(b) A loudspeaker producing sound of constant frequency is placed near the open end of a pipe, as shown in Fig. 4.1.

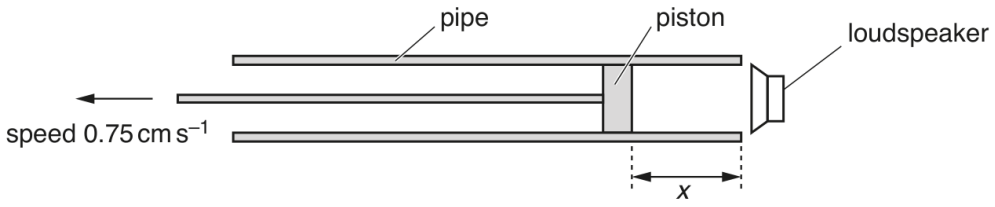


Fig. 4.1

A movable piston is at distance x from the open end of the pipe. Distance x is increased from $x = 0$ by moving the piston to the left with a constant speed of 0.75 cm s^{-1}.

The speed of the sound in the pipe is 340 m s^{-1}.

(i) A much louder sound is first heard when $x = 4.5$ cm. Assume that there is an antinode of a stationary wave at the open end of the pipe.

Determine the frequency of the sound in the pipe.

frequency = ... Hz [3]

(ii) After a time interval, a second much louder sound is heard. Calculate the time interval between the first louder sound and the second louder sound being heard.

time interval = ... s [2]

14 (b) A stationary sound wave in air has amplitude A. In an experiment, a detector is used to determine A^2. The variation of A^2 with distance x along the wave is shown in Fig. 4.1.

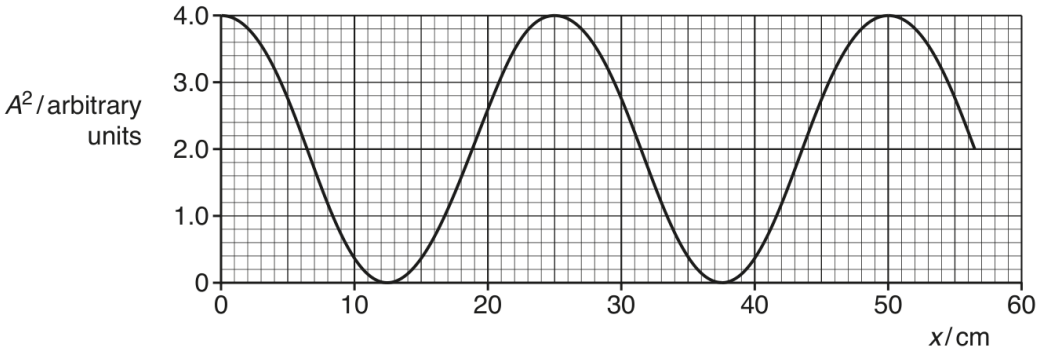


Fig. 4.1

(i) State the phase difference between the vibrations of an air particle at $x = 25\,\text{cm}$ and the vibrations of an air particle at $x = 50\,\text{cm}$.

phase difference = ... ° [1]

(ii) The speed of the sound in the air is $330\,\text{m s}^{-1}$. Determine the frequency of the sound wave.

frequency = ... Hz [3]