Waves

For Examiner's Use

1 Fig. 2.1 shows the variation with distance x along a wave of its displacement d at a particular time.

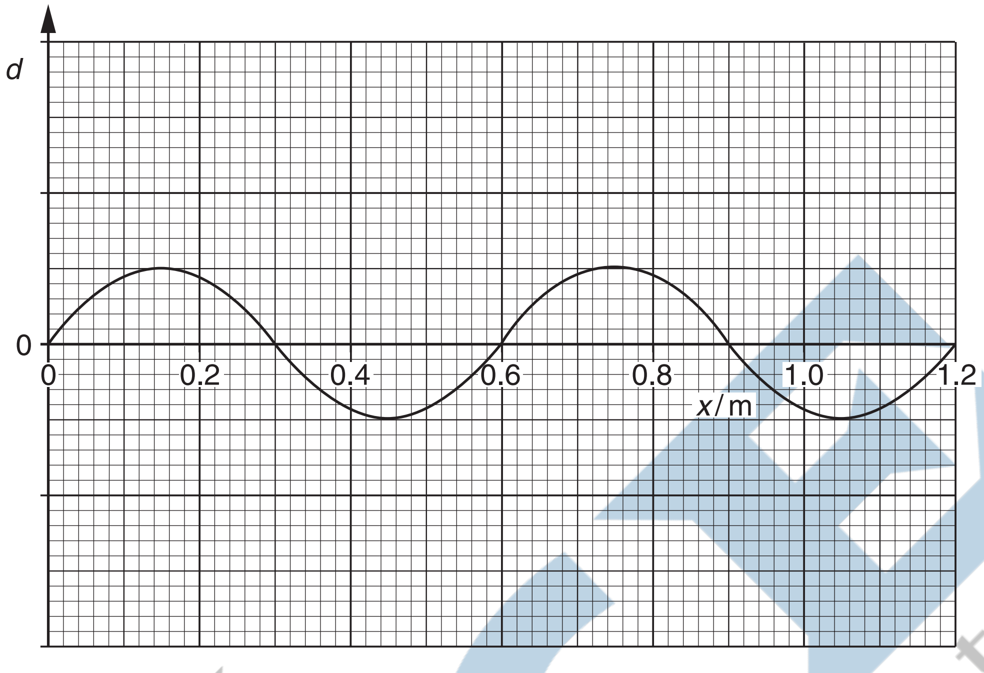

Fig. 2.1

The wave is a progressive wave having a speed of $330\,m\,s^{-1}$.

(a) **(i)** Use Fig. 2.1 to determine the wavelength of the wave.

wavelength = ... m

(ii) Hence calculate the frequency of the wave.

frequency = ... Hz [3]

(b) A second wave has the same frequency and speed as the wave shown in Fig. 2.1 but has double the intensity. The phase difference between the two waves is 180°.

On the axes of Fig. 2.1, sketch a graph to show the variation with distance x of the displacement d of this second wave. [2]

For Examiner's Use

2 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.

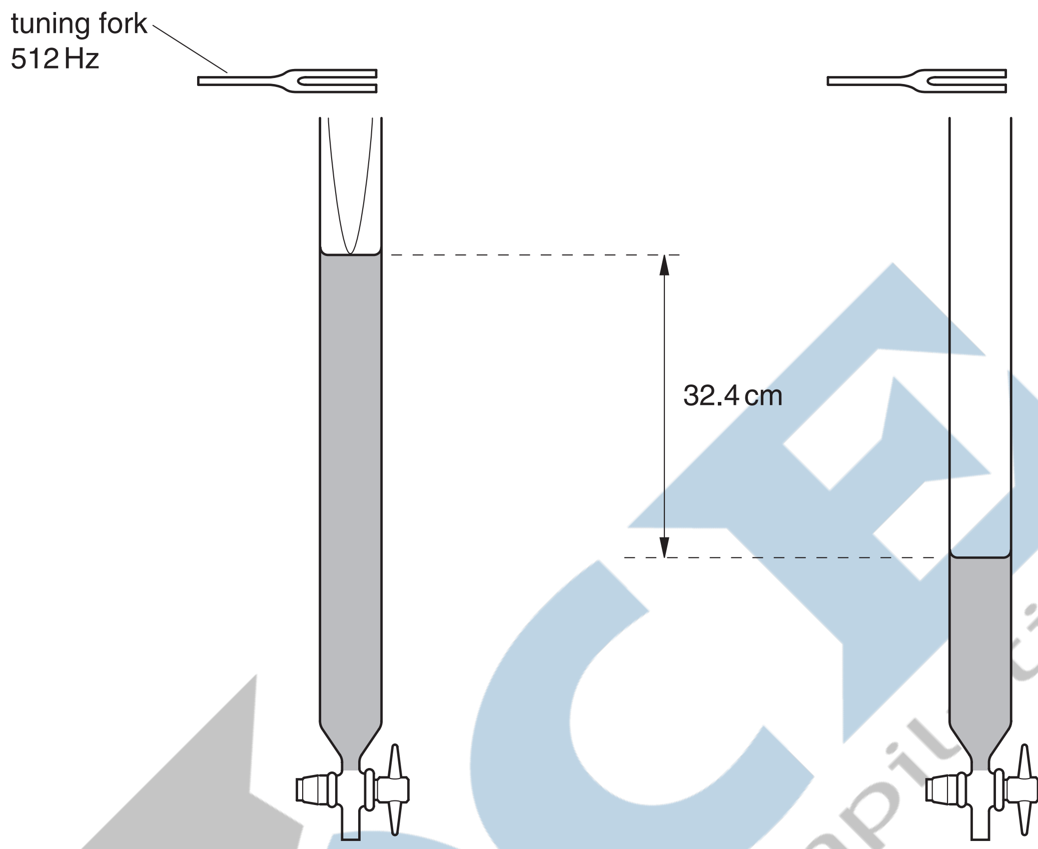

Fig. 6.1 **Fig. 6.2**

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]

For Examiner's Use

(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]

3 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.

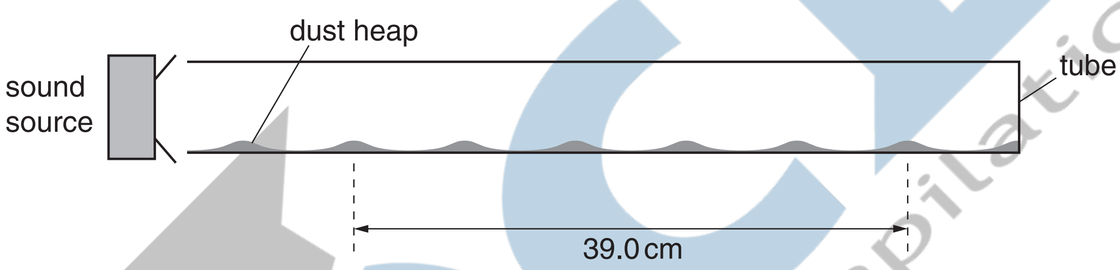

Fig. 5.1

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]

For Examiner's Use

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

(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.

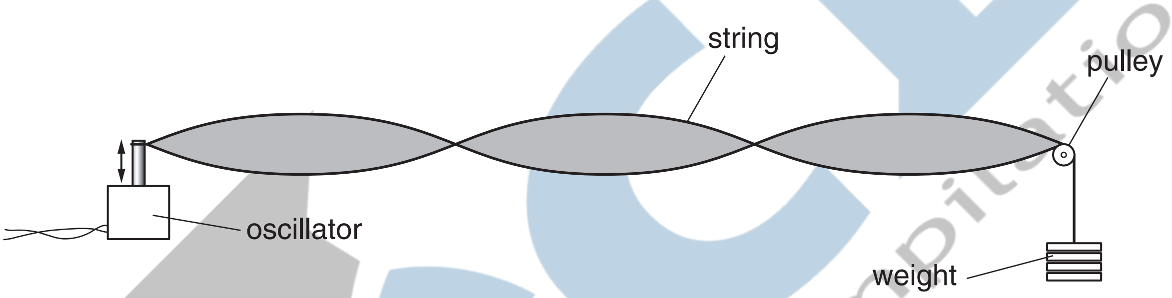

Fig. 5.1

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]

For Examiner's Use

(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]

5 The variation with time *t* of the displacement *x* of a point in a transverse wave T_1 is shown in Fig. 5.1.

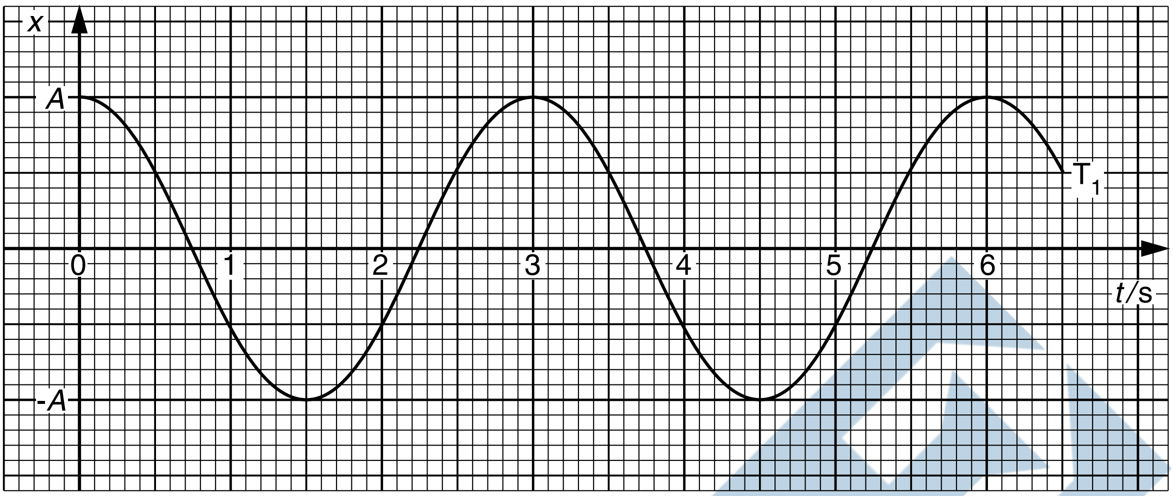

Fig. 5.1

(a) By reference to displacement and direction of travel of wave energy, explain what is meant by a *transverse wave*.

....

....[1]

(b) A second transverse wave T_2, of amplitude *A* has the same waveform as wave T_1 but lags behind T_1 by a phase angle of 60°. The two waves T_1 and T_2 pass through the same point.

(i) On Fig. 5.1, draw the variation with time *t* of the displacement *x* of the point in wave T_2. [2]

(ii) Explain what is meant by the *principle of superposition* of two waves.

....

....

....[2]

(iii) For the time $t = 1.0$ s, use Fig. 5.1 to determine, in terms of *A*,

1. the displacement due to wave T_1 alone,

displacement = ...

2. the displacement due to wave T_2 alone,

displacement = ...

3. the resultant displacement due to both waves.

displacement = ...

[3]

For Examiner's Use

6 The spectrum of electromagnetic waves is divided into a number of regions such as radio waves, visible light and gamma radiation.

(a) State three distinct features of waves that are common to all regions of the electromagnetic spectrum.

1. ....

2. ....

3. .... [3]

(b) A typical wavelength of visible light is 495 nm. Calculate the number of wavelengths of this light in a wave of length 1.00 m.

number = ... [2]

(c) State a typical wavelength for

(i) X-rays,

wavelength = ... m

(ii) infra-red radiation.

wavelength = ... m
[2]

For Examiner's Use

7 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.

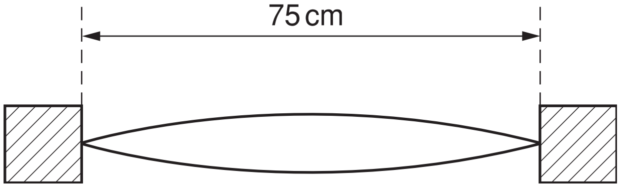

Fig. 4.1

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]

8 Fig. 5.1 shows the variation with time t of the displacements x_A and x_B at a point P of two sound waves A and B.

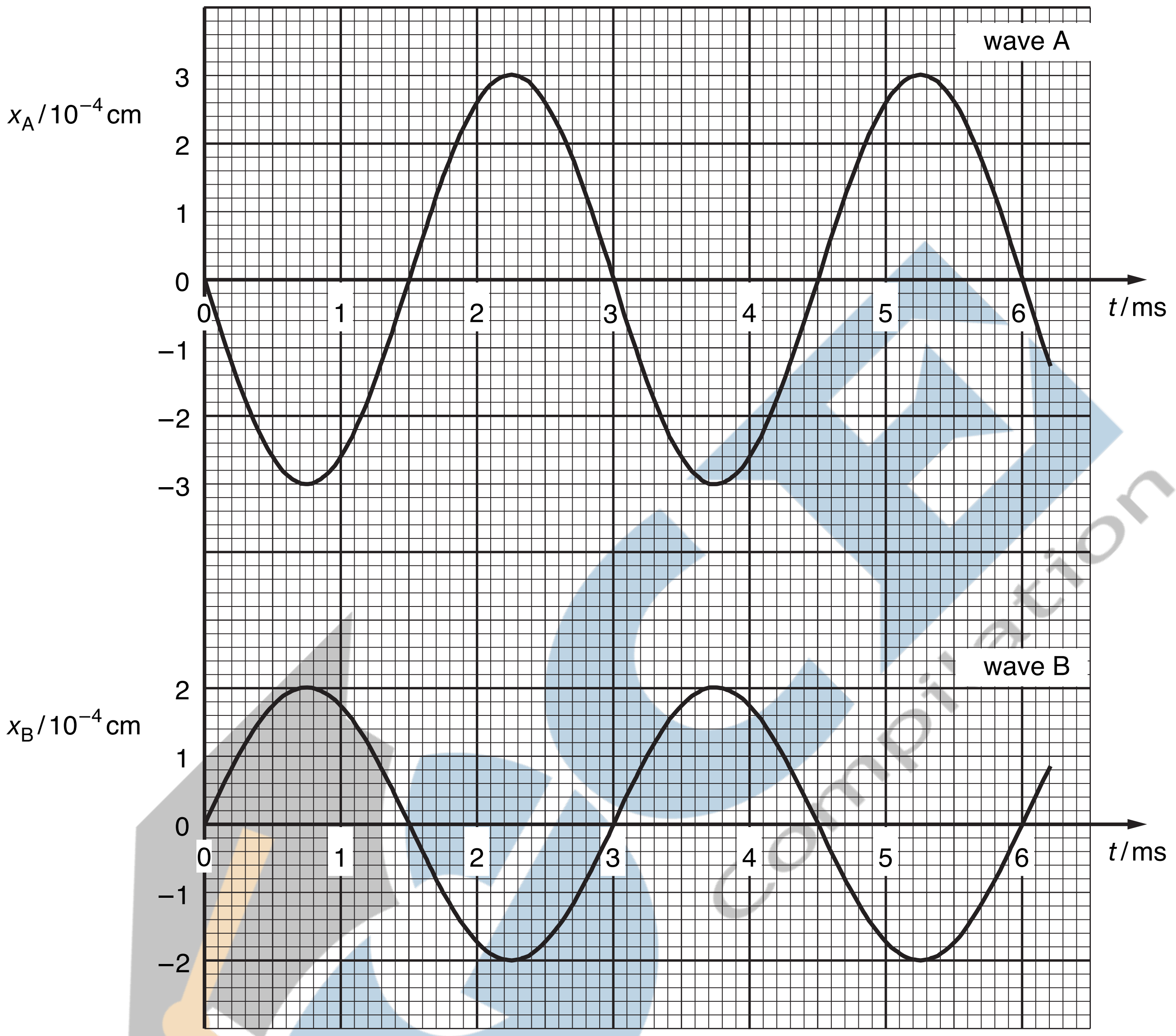

Fig. 5.1

(a) By reference to Fig. 5.1, state one similarity and one difference between these two waves.

similarity: ....

difference: .... [2]

(b) State, with a reason, whether the two waves are coherent.

....

.... [1]

(c) The intensity of wave A alone at point P is I.

For Examiner's Use

(i) Show that the intensity of wave B alone at point P is $\frac{4}{9}I$.

[2]

(ii) Calculate the resultant intensity, in terms of I, of the two waves at point P.

resultant intensity = ... I [2]

(d) Determine the resultant displacement for the two waves at point P

(i) at time $t = 3.0$ ms,

resultant displacement = ... cm [1]

(ii) at time $t = 4.0$ ms.

resultant displacement = ... cm [2]

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

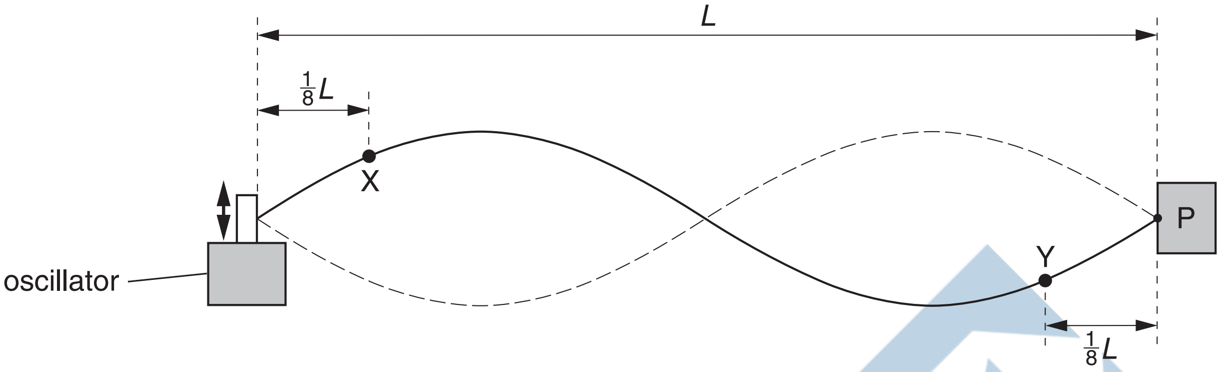

Fig. 5.1

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]

For Examiner's Use

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

speed = ... [1]

(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]

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

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.

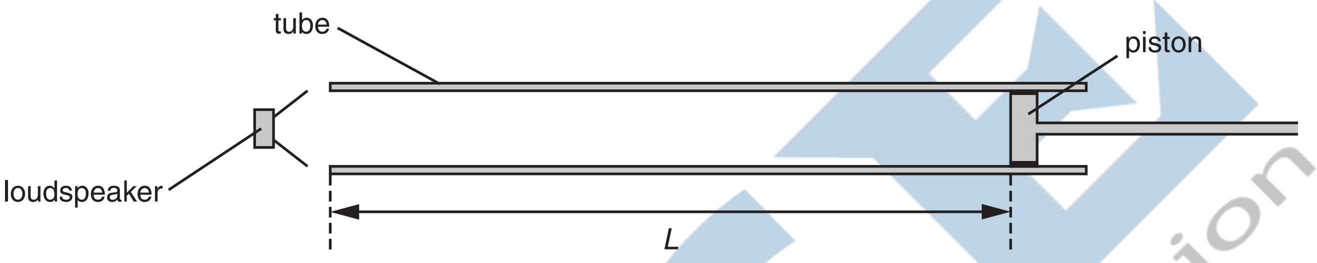

Fig. 4.1

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 $330\,\text{m}\,\text{s}^{-1}$.

(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.

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

frequency = ... Hz [3]

5 **(a)** A source of sound has frequency *f*. Sound of wavelength λ is produced by the source.

(i) State

1. what is meant by the *frequency* of the source,

....

....[1]

2. the distance moved, in terms of λ, by a wavefront during *n* oscillations of the source.

distance = ...[1]

(ii) Use your answers in **(i)** to deduce an expression for the speed *v* of the wave in terms of *f* and λ.

[2]

(b) The waveform of a sound wave produced on the screen of a cathode-ray oscilloscope (c.r.o.) is shown in Fig. 5.1.

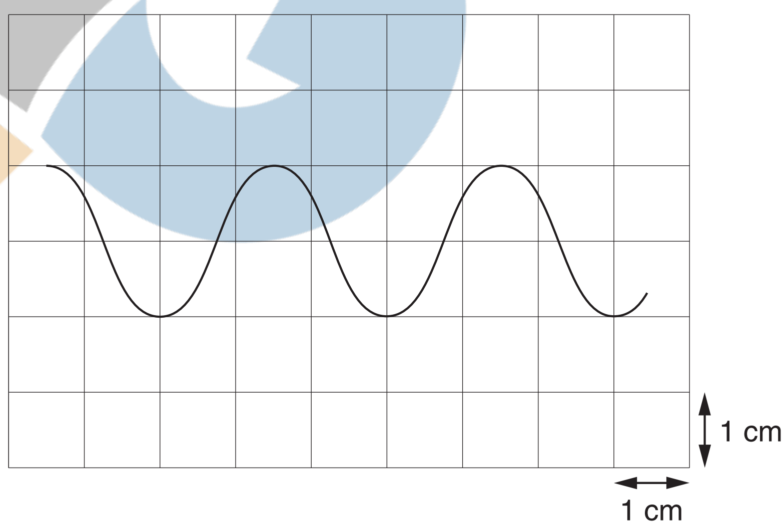

Fig. 5.1

The time-base setting of the c.r.o. is 2.0 ms cm^{-1}.

For Examiner's Use

(i) Determine the frequency of the sound wave.

frequency = ...Hz [2]

(ii) A second sound wave has the same frequency as that calculated in **(i)**. The amplitude of the two waves is the same but the phase difference between them is 90°.

On Fig. 5.1, draw the waveform of this second wave. [1]

5 A student is studying a water wave in which all the wavefronts are parallel to one another. The variation with time *t* of the displacement *x* of a particular particle in the wave is shown in Fig. 5.1.

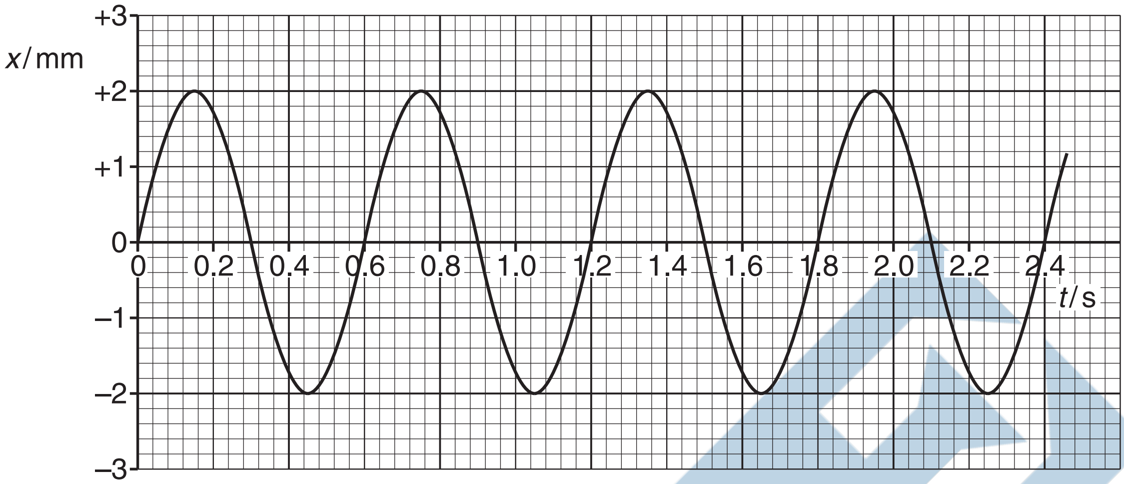

Fig. 5.1

The distance *d* of the oscillating particles from the source of the waves is measured. At a particular time, the variation of the displacement *x* with this distance *d* is shown in Fig. 5.2.

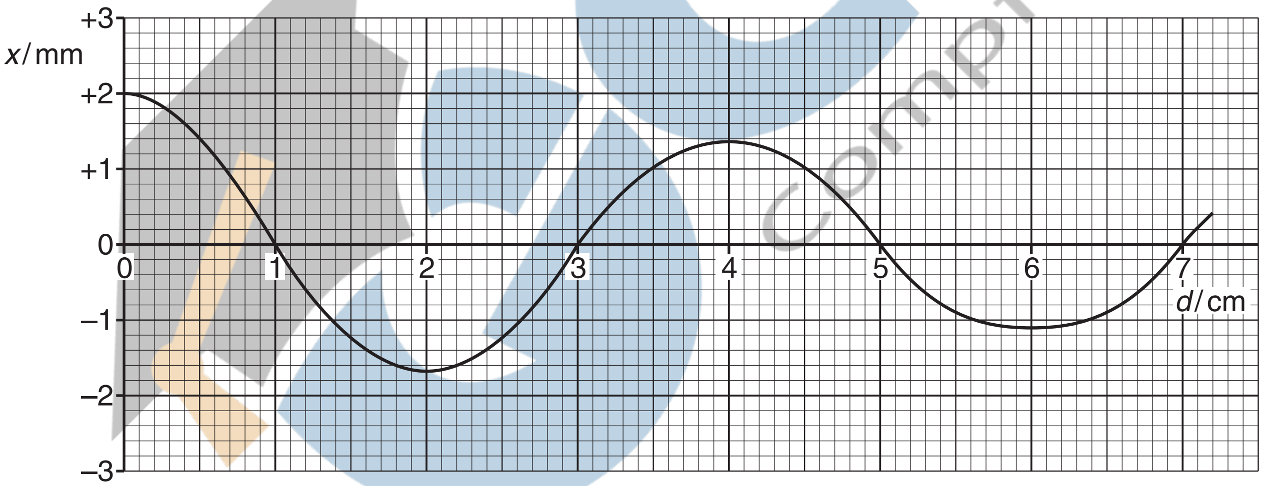

Fig. 5.2

(a) Define, for a wave, what is meant by

(i) *displacement*,

....

.... [1]

(ii) *wavelength*.

....

.... [1]

For Examiner's Use

(b) Use Figs. 5.1 and 5.2 to determine, for the water wave,

(i) the period T of vibration,

T = ... s [1]

(ii) the wavelength λ,

λ = ... cm [1]

(iii) the speed v.

v = ... $cm\,s^{-1}$ [2]

(c) **(i)** Use Figs. 5.1 and 5.2 to state and explain whether the wave is losing power as it moves away from the source.

....

....

.... [2]

(ii) Determine the ratio

$$\frac{\text{intensity of wave at source}}{\text{intensity of wave 6.0 cm from source}}.$$

ratio = ... [3]

6 **(a)** A transverse progressive wave travels along a stretched string from left to right. The shape of part of the string at a particular instant is shown in Fig. 6.1.

For Examiner's Use

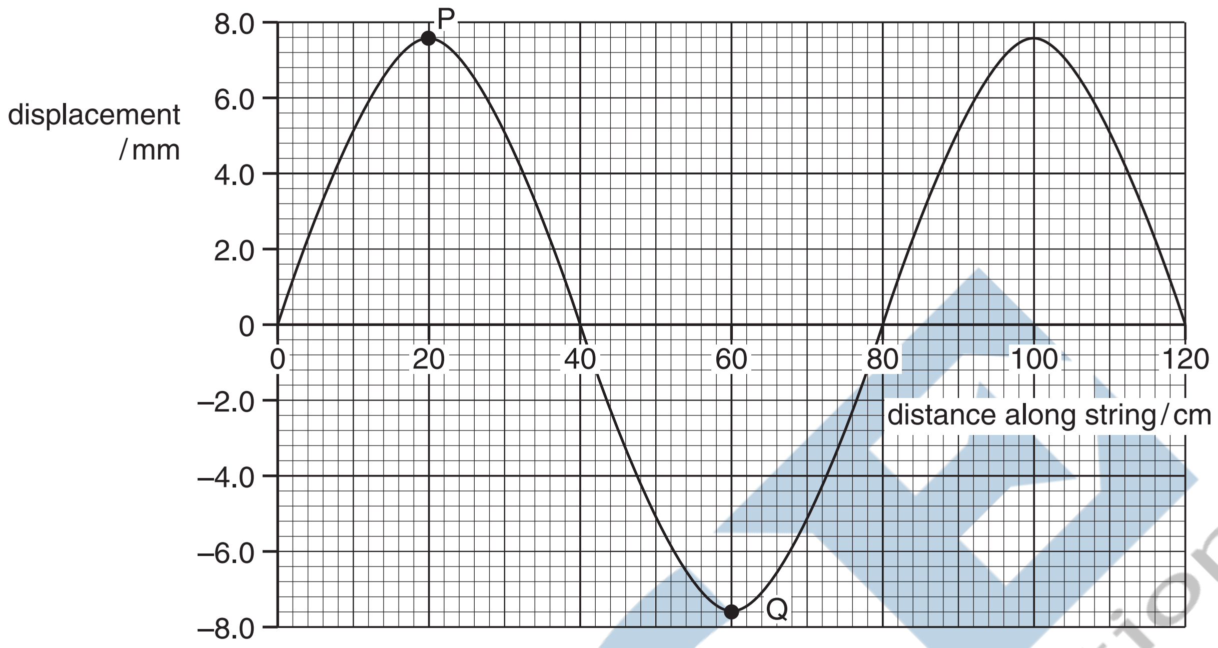

Fig. 6.1

The frequency of the wave is 15 Hz.
For this wave, use Fig. 6.1 to determine

(i) the amplitude,

amplitude = ... mm [1]

(ii) the phase difference between the points P and Q on the string,

phase difference = ... [1]

(iii) the speed of the wave.

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

(b) The period of vibration of the wave is *T*. The wave moves forward from the position shown in Fig 6.1 for a time 0.25 *T*. On Fig. 6.1, sketch the new position of the wave. [2]

(c) Another stretched string is used to form a stationary wave. Part of this wave, at a particular instant, is shown in Fig. 6.2.

For Examiner's Use

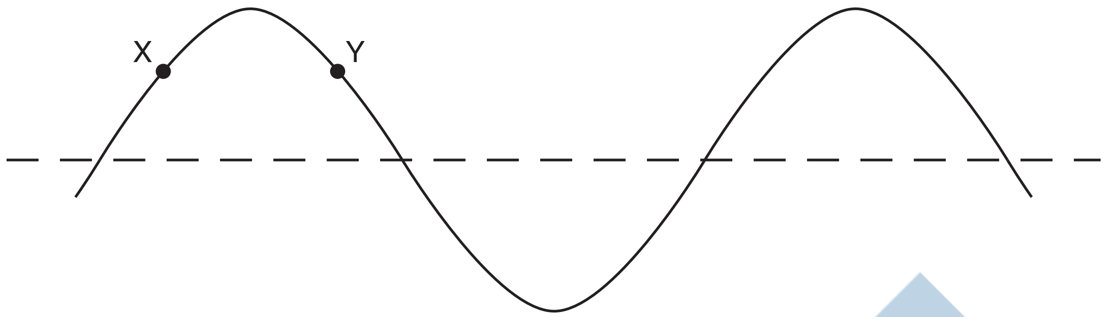

Fig. 6.2

The points on the string are at their maximum displacement.

(i) State the phase difference between the particles labelled X and Y.

phase difference = ... [1]

(ii) Explain the following terms used to describe stationary waves on a string:

antinode: ....

node: ....
[1]

(iii) State the number of antinodes shown on Fig. 6.2 for this wave.

number of antinodes = ... [1]

(iv) The period of vibration of this wave is τ. On Fig. 6.2, sketch the stationary wave 0.25τ after the instant shown in Fig. 6.2. [1]

