WAVE SUPERPOSITION

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 **(a)** Explain what is meant by the term *interference*.

....

....

....

.... [2]

(b) A Kundt's tube is an experimental acoustical instrument that serves to measure the speed of sound in different medium.

It comprises of a long horizontal tube, containing a fine powder, which is closed at one end. A loudspeaker connected to a signal generator is positioned at the other end. The device is shown in Fig 4.1 and the signal generator is set to a frequency of **400 Hz**.

From the *interference* of waves resulting in stationary waves being formed, an interesting pattern can be observed as seen in Fig 4.1.

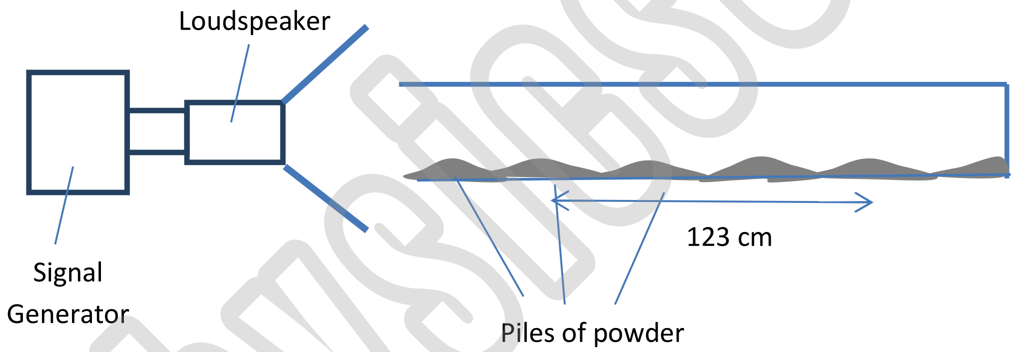


Fig 4.1

(i) Label the positions of nodes (**N**) and antinodes (**A**) on Fig. 4.1

[1]

(ii) Explain the formation of the piles of fine powder at the positions shown on Fig 4.1.

....

....

....

.... [3]

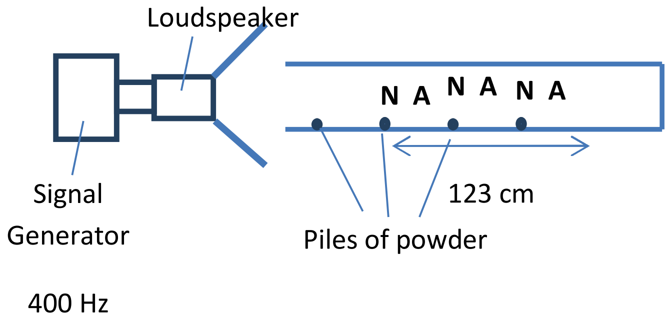
(iii) Hence or otherwise, determine the speed of the sound waves in that medium.

Speed of Sound = ... m s^{-1} [2]

ThePhysicsCafe

Ans (a)(i) Interference is observation in the **variation of the intensity** of the resultant wave when two of more waves meet due to the resultant displacement being given by the vector sum of the displacement of the individual wave.

(b) (i)



(b)(ii) When the sound wave that are produced by the source is **reflected** at the glass boundary with a **phase difference of** □.

The incident and reflected wave **overlaps** and as they have the **speed** and **frequency**, resulting in the formation of nodes and antinodes of a **standing wave** if the length of the tube is given by odd multiples of □/4.

The **piles of power gather at the nodes** as at the nodes no oscillation occurs.

(b)(iii) Wavelength of stationary wave
=123 X 2/3 = 82 cm

Hence speed of wave
= 400 Hz X 0.82 m = 328 = 330 m

2 **(a)** The wave nature of light may be demonstrated using the phenomena of interference.

Describe an experiment to show how interference may be demonstrated using light. You may use a diagram to illustrate your answer.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………[3]

(b) A microphone, connected to a cathode ray oscilloscope (c.r.o.), is placed at a distance of **1.2 m** in front of a loudspeaker connected to a source of fixed frequency. The intensity of sound measured at this position is **0.65 W m^{-2}**. The time base of the c.r.o. was set at **0.50 ms cm^{-1}** and the display on the c.r.o. is shown in Fig.8.1.

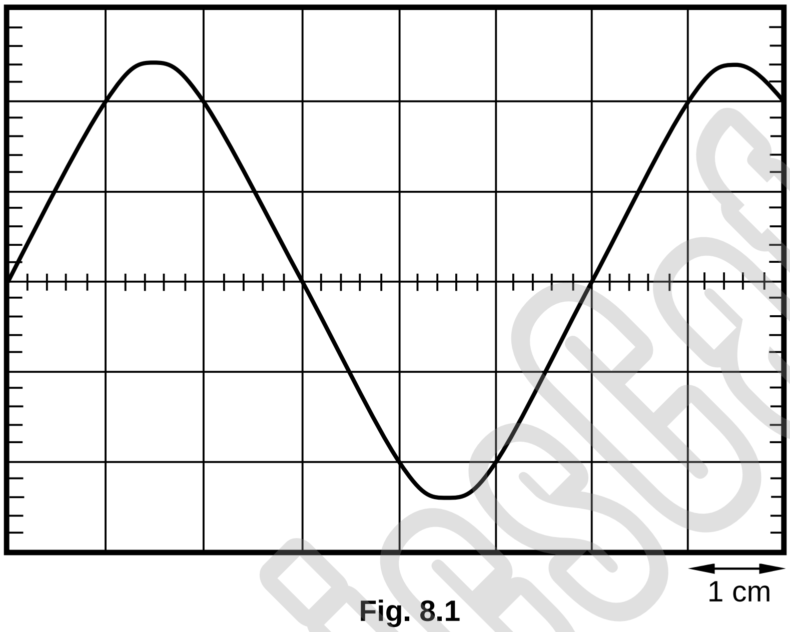


Fig. 8.1

(i) Determine the frequency of the sound wave.

frequency = ……………………………… Hz [2]

(ii) The speed of sound in air is given as **330 m s^{-1}**.
Calculate the wavelength of the sound wave from the loudspeaker.

wavelength = ……………………………… m [2]

(iii) The same loudspeaker is now placed outdoors. A man stands in front of the loudspeaker at a distance **5.5 m** away. Determine the intensity of the sound that the man hears at this distance.

intensity = ……………………………. W m^{-2} [2]

(c)

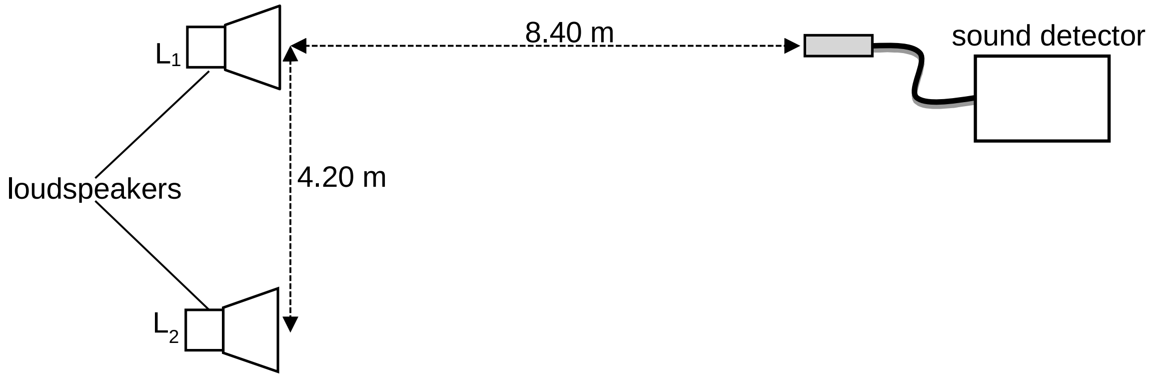


Fig. 8.2

Two identical loudspeakers, L_1 and L_2, connected to the same source as **(b)**, are placed **4.20 m** apart. A sound detector is placed **8.40 m** away from L_1, as shown in Fig. 8.2.

(i) Show that the distance between L_2 and the sound detector is **9.39 m**.

[1]

(ii) Hence, determine whether the intensity at the sound detector is a high or low.

[3]

(iii) The intensity of sound due to L_1 alone at sound detector **8.4 m** away is I.

Show, in terms of I, the intensity at the sound detector due to both L_1 and L_2 is $3.6I$.

[3]

(iv) The loudspeaker L_2 is now moved towards the sound detector along the axis shown in Fig. 8.3.

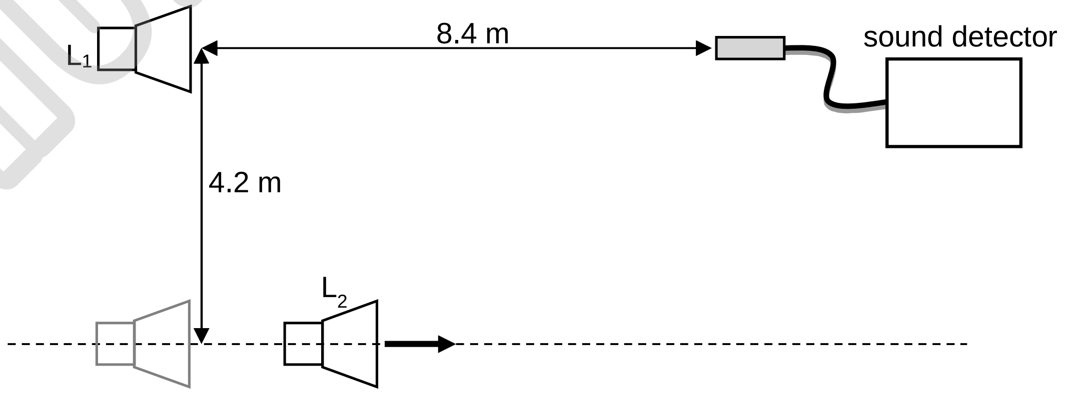


Fig. 8.3

Describe and explain the observation at the sound detector as L_2 is moved towards the sound detector, until L_2 is also **8.4 m** away from the detector.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[2]

(d) Noise cancellation headphones comes with embedded microphones, and actively makes use of interference to reduce noise that the listener hears.

Explain how this is achieved.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[2]

Ans **a** Diagram (if drawn) must show light source (e.g. light / laser), object causing interference (i.e. double slit) and means of observation (e.g. screen)
Light source must be monochromatic and coherent

OR
Description of setup must mention the above items.
Instead of two bright fringes of the screen, a fringe pattern containing alternating light and dark fringes is observed.

Note: drawing of wavefronts / ripples is not accepted as light wave are in multiple planes

bi From Fig. 8.1, period, T = 6 x 0.50 x 10^{-3} s = 3.0 x 10^{-3} s
Hence, frequency = 1/T = 333.33 = 333 Hz

bii Using v = f λ,
330 = 333.33 λ
λ = 0.99 m

biii Since Intensity ∝ $(1 / r)^2$,
Using ratio, $\frac{I_{5.5}}{I_{1.2}} = \left(\frac{r_{1.2}}{r_{5.5}}\right)^2$
➔ $I_{5.5} = \left(\frac{1.2}{5.5}\right)^2 0.65 = 0.031\ W\ m^{-2}$

ci Using Pythagoras' Theorem,
Distance = $\sqrt{8.40^2 + 4.20^2}$ = 9.391
= 9.39 m **[shown]**

cii path difference = 9.391 – 8.40
= 0.99 m

Hence path difference = λ or phase difference = 2π rad
The waves from both speakers will arrive in phase at the sound detector.

Hence constructive interference occurs and the intensity at the sound detector is a high.

ciii Using intensity ∝ $1/r^2$, intensity due to L_2 only at 9.39 m away from sound detector is

$$\frac{I_2}{I} = \left(\frac{8.4}{9.39}\right)^2$$

➔ $I_2 = 0.8003\ I$

Since intensity ∝ amplitude^2 and letting amplitude of sound due to L_1 alone at detector be *a*,

$$\frac{I}{I_2} = \left(\frac{a}{a_2}\right)^2 \Rightarrow \frac{I}{0.8003\ I} = \left(\frac{a}{a_2}\right)^2$$

➔ $a_2 = 0.8946\ a$

Since from 8cii, constructive interference takes place,
resultant amplitude at sound detector = *a* + 0.8946*a* = 1.8946*a*
Hence,

$$\frac{I_{resultant}}{I} = \left(\frac{1.8946\ a}{a}\right)^2$$

➔ $I_{\text{resultant}} = 3.6\ I$ **[shown]**

civ Since the path difference is equal to 0 λ when L_2 is 8.4 m from sound detector, there must be a position in between where the path difference is 0.5 λ.
Hence a low intensity (at path difference 0.5 λ) followed by a high intensity (at path difference 0 λ) will be observed at the sound detector.

OR

As L_2 moves to 8.4 m away from sound detector, path difference drops from 1λ to 0.5λ to 0λ.
Hence, intensity of sound drops from loud (maximum) to soft (minimum) to loud (maximum) respectively.

d The microphones receive sound from the surrounding and the headphones then produces the same sound but in antiphase (π radian out of phase).
This causes destructive interference of the sound from the surrounding and reduces the noise perceived by the listener.

3 **(a)** Explain what is meant by a *progressive wave*.

....

....

.... [1]

(b) Sound is propagated in air as a longitudinal progressive wave, in which there is a repeated sequence of displacements of the air particles. Fig. 2.1a illustrates nine particles, equally spaced along the line **AB**, in still air.

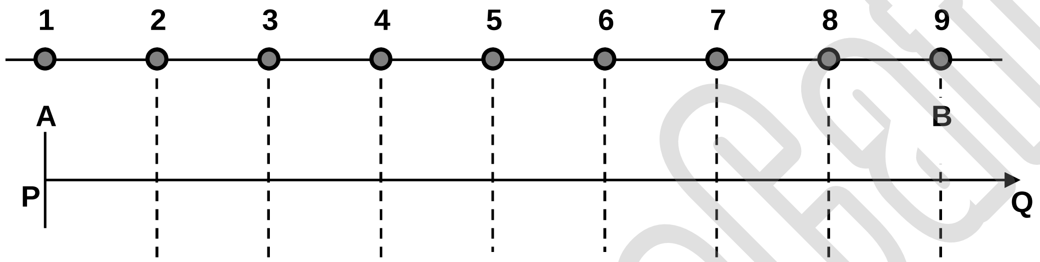


Fig. 2.1a

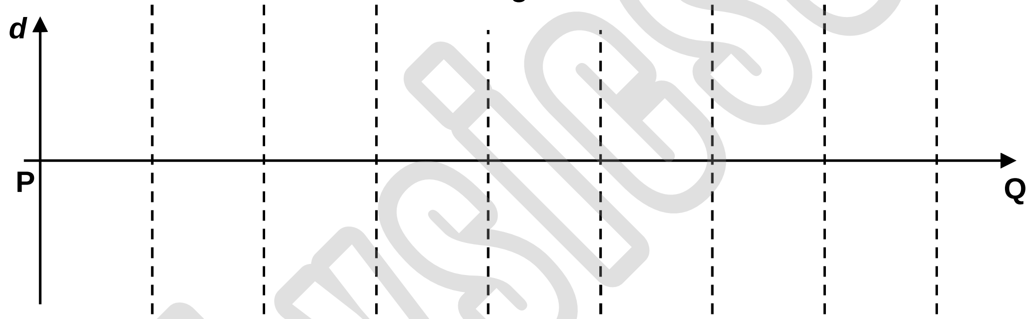


Fig. 2.1b

(i) A sound wave of wavelength equal to the distance between **A** and **B** is sent through the air in the direction of **PQ**. On line **PQ** on Fig. 2.1a, draw the possible positions of the nine particles in the wave relative to their undisturbed positions which they occupy in still air, when the sound wave propagates through the particles. [1]

(ii) Using **(b)(i)**, sketch a graph showing how the displacement *d* of the particles from their undisturbed positions vary along **PQ** on Fig. 2.1b. Take direction to the right as positive. [1]

(iii) A sound wave can also be described in terms of a repeated sequence of changes in pressure. On Fig. 2.1b, identify, and label with **H,** a point where the pressure is the highest. Justify your answer.

....

....

....

.... [2]

....

(iv) A loudspeaker, generating a sound wave with a wavelength magnitude equal to AB, and a screen are placed at **A** and **B** respectively. Describe and explain the changes, if any, to Fig. 2.1b over time as compared to the current scenario.

....

....

....

....

.... [2]

(c) A stereo system in a large hall has two identical speakers, S_1 and S_2, **1.2 m** apart. The amplitude of the output of each speaker is proportional to the voltage across its terminals. The voltage input to each speaker is adjusted by means of a balance control. The arrangement is shown in Fig. 2.2.

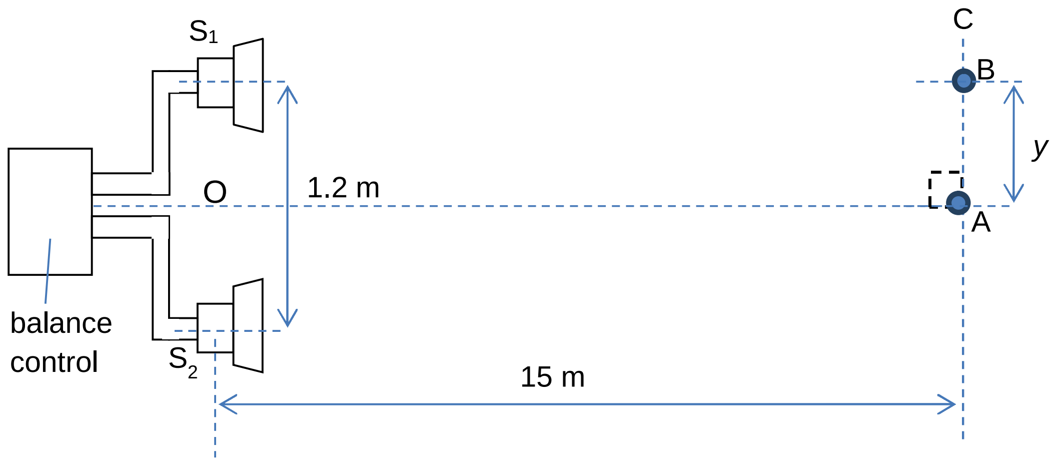


Fig. 2.2 (not to scale)

Initially, the speakers are emitting signals of frequency **1000 Hz** which are in phase. The balance control is set such that there is a voltage of **6 V r.m.s.** across each speaker. An observer hears a loud sound of intensity I_{max} at A. As he moves along the line AC, **15 m** away from the speakers, he observes that the intensity first falls to zero at point B, a distance *y* from A. The speed of sound in air is **330 m s^{-1}**.

(i) Determine the distance *y*.

[2]

y = ……………. m

(ii) Determine the next higher frequency of the speaker such that point B would also be a point of zero intensity.

frequency = …………………. Hz [3]

(iii) With the speakers emitting the original signal frequency of **1000 Hz**, the balance control is now adjusted such that the voltages across S_1 and S_2 are **3.0 V r.m.s**. and **9.0 V r.m.s**. respectively. In terms of I_{max}, determine the new intensity at point B.

intensity = ……………….. [3]

ThePhysicsCafe

Ans **(a)** A progressive wave is a wave in which **energy is transferred from one point to another by means of vibrations or oscillations** within the wave.

(b)

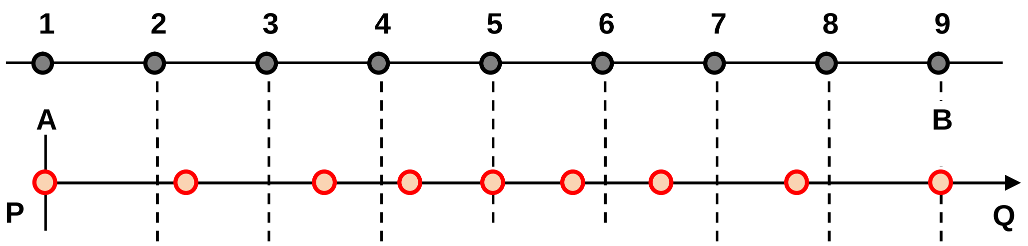


Fig. 2.1a

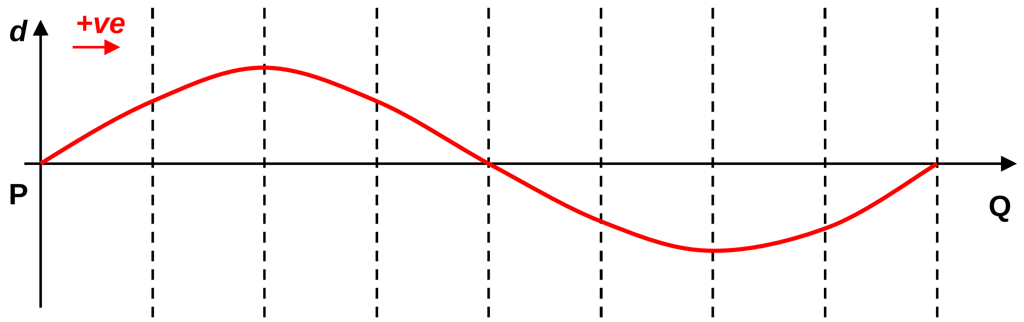


Fig. 2.1b

(i) For part (i), positions of particles must conform to 1 wavelength, with clear differences in displacements of particles.

(ii) For part (ii), wave drawn must correspond to diagram in (i) and displacement of particles to the right is taken to be positive on the graph.

(iii) Point H, a point of high pressure, **occurs at where particle 5 is** as this is where **compressions occur due to neighbouring air particles 4 and 6 coming closer to one another.**

Identifying and labelling of H correctly at particle 5.

(iv) As a **stationary wave is being formed, the wave will not progress and each particle will oscillate with different amplitudes**.

In the current scenario, the **wave will progress towards Q with each particle moving left and right, reaching the same amplitude** over time.

(c) (i) Using $x = \frac{\lambda D}{a}$ where $\lambda = \frac{v}{f}$

$y = \frac{(\frac{330}{1000})(15)}{(1.2 \times 2)}$, x is twice that of y (x = 2y) since B is at minimum intensity

$y = 2.1$ m

(ii) Since B is a point of minimum intensity, the path difference of S_1 and S_2 at point B,

$S_1B - S_2B = \frac{\lambda}{2} = \frac{0.33}{2} = 0.165\ m$

For other wavelengths *λ*, point B will be at zero intensity if the path difference is odd multiple of $\frac{\lambda}{2}$.

Therefore,

$(2n+1)\frac{\lambda}{2} = 0.165\text{ m where } n = 1$

$\lambda = 0.11\text{m}$

Using $f = \frac{v}{\lambda}$,

$f = \frac{330}{\lambda}$

f = 3000 Hz

(iii) Since amplitude ∝ voltage and amplitude^2 ∝ intensity,

initially at A, constructive interference occurs as the two waves meet in phase to give $I_{max.}$

Thus amplitude proportional to 6 V + 6 V = 12 V,

hence $I_{max} \propto (12\text{ V})^2 = 144\text{ V}^2$

At B, destructive interference occurs as two waves meet in antiphase,

Thus amplitude proportional to 6 V - 6 V = 0 V giving $I_{min} = 0$.

When the speakers are adjusted to 9 V and 3 V,

the resultant amplitude at B is proportional to 9 V – 3 V = 6 V.

Hence $I_{min} \propto (6\text{ V})^2 = 36\text{ V}^2$

$I_{min} = \frac{1}{4} I_{max}$

ThePhysicsCafe