AQA

A Level

A Level Physics

WAVES: Combining Waves

(Answers)

Name:

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Total Marks: /30

1. To produce coherent microwaves a single source is positioned behind a metal sheet in which two slits have been cut at a distance of 80 cm from each other. The wavelength of the microwaves produced is 0.1 m.

Total for Question 1: 15

(a) State the principle of superposition of waves and illustrate it schematically. [2]

> **Solution:** When two waves meet at a point, the resultant displacement vector at that point is the sum of the displacement vectors of the individual waves.
> Graph should show constructive and/or destructive cases, or somewhere between e.g. sine wave + cosine wave = zero amplitude.

(b) What is meant by 'coherent microwaves'? [1]

> **Solution:** The microwaves produced must have a constant phase difference and be of the same frequency.

Arnav walks in a straight line parallel to the slits and on the opposite side of the metal sheet from the source. He notices that there are amplitude maxima and minima and that the maxima are separated by a distance of 0.75 m.

(c) Explain, in terms of the path difference, why he encounters a series of amplitude maxima and minima. [2]

> **Solution:** For constructive interference a path difference of $n\lambda$ is required; for destructive $(n + 1/2)\lambda$.

(d) How far away from the metal sheet is Arnav? You may assume that the approximations that apply to light are also valid for sound. [2]

Solution: 6 m

(e) Heather asks Arnav to repeat the calculation using a different experimental setup. This time, the slits' separation is 6 m, the wavelength of the microwaves is 0.75 m and maxima are 0.75 m apart. If he uses the same method to calculate the distance between himself and the metal sheet, will he obtain a valid result? Justify your answer. [2]

Solution: Separation is again 6 m. However, this means $a \approx D$ and so the $\lambda = \frac{ax}{D}$ relationship is invalid.

(f) The wavelength of a light source can be calculated experimentally using a double slit. Outline how you would do this, taking care to include details of the experimental setup, any measurements that must be taken and any calculations required. [3]

> **Solution:** Shine coherent light through the slits (e.g. a monochromatic laser) onto a screen.
> Measure the fringe spacing, x, the slits-screen spacing, D, and the slit separation, a.
> $\lambda = \frac{ax}{D}$.

(g) The wavelength of light can also be calculated by shining light through a diffraction grating. Show, by drawing a diagram, that $n\lambda = d\sin\theta$, where n is an integer, λ is the wavelength of the source, d is the slit spacing and θ is the angle between the beam and the perpendicular to the grating. [3]

> **Solution:** For constructive interference, path difference must be $n\lambda$
> Diagram should show a triangle formed by the slit separation, $n\lambda$ and the perpendicular to the beam.
> Trigonometry reveals $n\lambda = d\sin\theta$.

2. Standing waves can be produced using both transverse and longitudinal progressive waves. This question explores how the notes produced on various simple instruments are affected by the tubes' and strings' lengths.

Total for Question 2: 15

(a) State two differences between standing waves and progressive waves. [2]

Solution: Energy: no net transfer in a standing wave; transfer in direction of wave in a progressive wave.
Phase: all parts of a standing wave between adjacent nodes are in phase and on different sides of a node are in antiphase; phase changes over a complete wave cycle in progressive waves.
Amplitude: max A at antinodes and zero at nodes for a standing wave; all parts of a progressive wave have the same amplitude.

(b) The tension in a cello string is related to the speed of the progressive wave travelling along it by the relationship $v = \sqrt{\frac{T}{\mu}}$, where μ is a constant and T is the tension. For a 70 cm long cello string held with a tension of 10 N the frequency of the first harmonic is 65 Hz. Calculate the value of the constant μ. [3]

Solution: 1.2×10^{-3}

(c) Explain, in terms of the amplitude of vibrations, the cause of the differences between at standing wave in a tube with two open ends and one in a tube with a closed end. [2]

Solution: A closed end requires that the air is stationary i.e. it has an amplitude of zero. At an open end, oscillations of the air are at their greatest amplitude. This results in nodes forming at closed ends and antinodes at open ends.

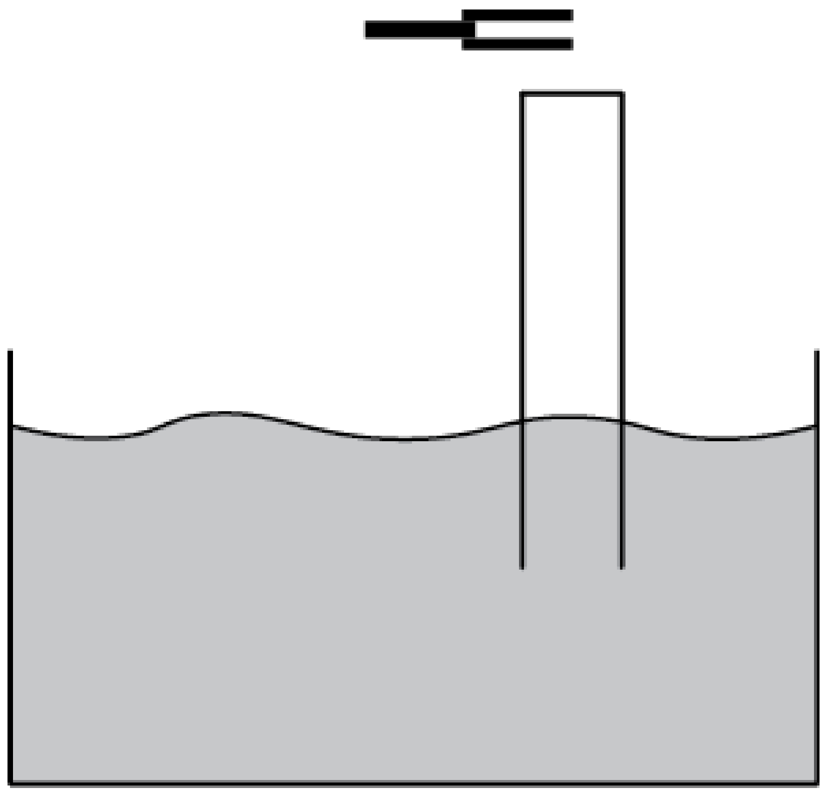

Figure 1: A partially submerged tube with a vibrating tuning fork held above it.

(d) Figure 1 shows a tube which is partially submerged in a bowl of water. Using a selection of tuning forks, a tube with a single open end and a bowl of water, explain how you would go about calculating the speed of sound. [3]

Solution: Experimental setup: insert tube's open end into the water; hold a vibrating tuning fork above the tube and lower the tube until the sound is loudest. This length, when the tube is resonating, corresponds to the first harmonic.
Repeat the procedure for the various forks, recording length L and fork frequency f.
Plot a graph of L against $1/f$.
Since the tube is closed at one end, $\lambda = 4L \rightarrow v = f\lambda = 4fL \rightarrow L = v/4f$
Therefore, speed is 4x gradient.

(e) Sketch on Figure 1 the standing wave produced at the second possible harmonic frequency. [2]

Solution: Should be harmonic corresponding to $3f_0$ i.e. the length of the tube = $3/4\ \lambda$.
2 nodes and 2 antinodes.

(f) George is blowing across the top of a 350 cm glass tube. He produces a note with a frequency of 196 Hz. By calculating the frequencies of the first harmonics, determine whether the tube is open at one or both ends. The speed of sound in air is 343 ms^{-1}. [3]

Solution: Must be open at both: produces a note with a frequency equal to an even multiple of the first harmonic (irrespective of which of the calculated first harmonics is used).