Edexcel

A Level

A Level Physics

WAVES: Combining Waves (Answers)

Name:

MME

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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. Arnav is using a microwave detector on the other side of the metal sheet to better understand the ways in which waves combine.

Total for Question 1: 10

(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.

(c) Arnav walks in a straight line parallel to the slits and on the opposite side of the metal sheet from the source. 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) The wavelength of a light source can be calculated experimentally using a diffraction grating. Out-   [3]
line how you would do this, taking care to include details of the experimental setup, any measurements that must be taken and any calculations required.

> **Solution:** Shine coherent monochromatic light through the grating onto a screen.
> Measure the angle between bright fringes (numbered n, from centre outwards) and the central maximum
> Plot $\sin \theta$ against n
> Gradient will be λ/d since $n\lambda = d\sin\theta$; λ is equal to the gradient times the slit spacing.

(e) After finishing his microwave experiment Arnav is asked to calculate the wavelength of light pro-   [2]
duced by a laser. He measures the angle between the beam and the eighth-order maximum as
0.14°and uses a grating with a slit spacing of 1 mm. What is the wavelength of the light used?

> **Solution:** 310 nm

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

Total for Question 2: 10

(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) How would the fundamental frequency of the string change if its mass per unit length were doubled? [2]

> **Solution:** Reduces by factor of $1/\sqrt{2}$ i.e. 46 Hz

In tubes, standing waves are produced when the air column vibrates at specific frequencies. A closed end requires that the air is stationary, whilst at an open end oscillations of the air have their greatest amplitude. This results in nodes forming at closed ends and antinodes forming at open ends.

(d) 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).

3. Geoff is testing out different combinations of lenses. He has six identical convex lenses at his disposal, each with a focal length of 4 m.

Total for Question 3: 10

(a) By sketching a ray diagram, determine whether or not a diverging lens can produce a real image. [2]
Indicate on your diagram where the image will be.

> **Solution:** Rays will diverge; they cannot converge to produce a real image on a screen, irrespective of the screen's location.
> Image will be upright, virtual and on the same side of the lens as the object.

(b) Calculate the power of the following:
   i. A single lens of Geoff's. [1]
   ii. A combination of all six lenses. [1]

> **Solution:** 2.5 D
> 15 D

(c) Show how the effective focal length of a combination of identical convex lenses is related to their number and the focal length of an individual lens.   [2]

> **Solution:** $f_{total} = f_{individual}/n$

Geoff places a vase 1 m from a compound lens that he has constructed using some of his six identical lenses. The resultant magnification factor is 4.

(d) Calculate the distance to the image.   [1]

> **Solution:** 4 m

(e) How many of his six lenses are being used?   [3]

> **Solution:** 5