InkPhysics

ANSWER BOOK

Interference and Young's double slit

Waves · Year 12

AQA 3.3.2.1 · CIE 8.3.1, 8.3.2, 8.3.3, 8.3.4
OCR A 4.4.3(a)(i), 4.4.3(c), 4.4.3(d), 4.4.3(e), 4.4.3(f), 4.4.3(g)(i)

19 questions · 57 marks

NAVY EDITION

SECTION A · Warm-up

A1 Constructive interference: path difference = $n\lambda$ (1). Destructive interference: path difference = $(n + \frac{1}{2})\lambda$, where n is an integer (1). [2]

A2 Coherent sources have the same frequency (and wavelength) (1) and keep a constant phase difference between them over time (1). [2]

A3 $w = \lambda D/s$ (1), where w is the fringe spacing, λ the wavelength, D the distance from the slits to the screen, and s the slit separation (1). [2]

A4 Move the screen further from the slits, increasing D (1). Use a slit pair with a smaller separation s (1). (Since $w = \lambda D/s$, both changes increase w.) [2]

A5 Both slits are illuminated by the same wavefront from the one source (single slit), so the light at the two slits has the same frequency (1) and a constant phase difference (1). [2]

A6 A dark fringe (1). The path difference is $(n + \frac{1}{2})\lambda$, so the two waves arrive in antiphase and interfere destructively (1). [2]

SECTION B · Standard

B1 [3]
$w = \lambda D/s$ (1)
$= (600 \times 10^{-9} \times 1.5)/(0.50 \times 10^{-3})$ (1)
$w = 1.8$ mm (1)

B2 [3]
$\lambda = ws/D$ (1)
$= (2.4 \times 10^{-3} \times 0.40 \times 10^{-3})/2.0$ (1)
$\lambda = 480$ nm (1)

B3 [3]
$s = \lambda D/w$ (1)
$= (650 \times 10^{-9} \times 1.2)/(1.3 \times 10^{-3})$ (1)
$s = 0.60$ mm (1)

B4 [2]
Second bright fringe: path difference = $2\lambda = 2 \times 600$ nm (1)
$= 1200$ nm $= 1.2$ μm (1)

B5 $\lambda = v/f = 340/850 = 0.40$ m (1). Path difference = $0.60/0.40 = 1.5\lambda$ (1). A half-integer number of wavelengths means the waves arrive in antiphase, so the interference is destructive and the listener hears a minimum (a quiet point) (1). [3]

B6 $w = 21.6\ \text{mm}/8 = 2.7\ \text{mm}$ (1). $\lambda = ws/D = (2.7 \times 10^{-3} \times 0.40 \times 10^{-3})/1.8$ (1) $= 6.0 \times 10^{-7}\ \text{m} = 600\ \text{nm}$ (1). [3]

B7 Rearranging $w = \lambda D/s$: $D = ws/\lambda$ (1) $= (4.0 \times 10^{-3} \times 0.30 \times 10^{-3})/(633 \times 10^{-9})$ (1) $= 1.9\ \text{m}$ (1). [3]

SECTION C · Stretch

C1 $w = \lambda D/s = (500 \times 10^{-9} \times 2.0)/(0.25 \times 10^{-3})$ (1) [4]
$w = 4.0\ \text{mm}$ (1)
Halving s doubles w ($w \propto 1/s$) (1)
new $w = 8.0\ \text{mm}$ (1)

C2 Coherence keeps the phase difference between the two beams constant, so the bright and dark fringes stay in fixed positions (1); a single wavelength gives one fringe spacing so the fringes are sharp (1). With white light the central fringe is white (all wavelengths meet in phase there) (1), with coloured fringes either side that quickly overlap and wash out (1). [4]

C3 The two lamps are incoherent (1): they emit light with a randomly and rapidly changing phase difference (1). The positions of constructive and destructive interference shift far too quickly to be seen, so the pattern averages out to uniform brightness (1). [3]

C4 $w = \lambda D/s = (546 \times 10^{-9} \times 2.2)/(0.45 \times 10^{-3})$ (1) $= 2.67\ \text{mm} \approx 2.7\ \text{mm}$ (1). Fringes either side of the centre: $10\ \text{mm}/2.67\ \text{mm} = 3.7$, so 3 whole spacings fit each side (1). Number of bright fringes $= 2 \times 3 + 1 = 7$ (1). [4]

C5 Use of $w = \lambda D/s$ with $D = 1.4\ \text{m}$ (1). Pair P: $w = (650 \times 10^{-9} \times 1.4)/(0.30 \times 10^{-3}) = 3.0\ \text{mm}$ (1). Pair Q: $w = 1.5\ \text{mm}$ (1). Only pair P gives a spacing of at least 2.0 mm, so the student should use P; the slit width is not needed in the comparison (1). [4]

C6 Shine the laser normally through the double slits so a fringe pattern forms on the screen a few metres away, in a darkened room (1). Measure the slit-to-screen distance D with the tape measure (1). Measure the distance across many fringe spacings with the ruler and divide by the number of spacings to find w (1). Calculate the wavelength from $\lambda = ws/D$ (1). Uncertainty: use a large D so the fringes are widely spaced, measure across as many fringes as possible, and repeat the measurements and average (any two) (1). Safety: do not look into the beam or let reflections from shiny surfaces reach anyone's eyes (1). [6]