Unit 11 · Interference of Light

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 28

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

0.30 mm is 0.30×10^{-3} m, not 0.30×10^{-2} m (that is 0.30 cm). So $\beta = \dfrac{560 \times 10^{-9} \times 1.5}{0.30 \times 10^{-3}} = \mathbf{2.8\ mm}$, ten times her answer.

MARKING SCHEME

- ✓ The mistake: millimeters converted as 10^{-2} m.
- ✓ $d = 0.30 \times 10^{-3}$ m.
- ✓ $\beta = 2.8$ mm.

2 Show that

ANSWER A · 2

Bright: $xd/D = n\lambda$, so $x = n\beta$. Dark: $xd/D = (2n - 1)\lambda/2$, so $x = (n - \frac{1}{2})\beta$. So the n-th dark fringe is at $(n - ½)\beta$, halfway between the bright fringes at $(n - 1)\beta$ and $n\beta$.

MARKING SCHEME

- ✓ Bright at $n\beta$, dark at $(n - ½)\beta$.
- ✓ So each dark fringe is halfway between two bright ones.

3 Predict, then explain

ANSWER HA · 4

i. The pattern **shifts towards the covered slit**: light through the sheet is delayed, so the point where both paths are equal moves to the side of that slit.

ii. Extra optical path $= (\mu - 1)t = 0.5 \times 3.0\ \mu m = \mathbf{1.5\ \mu m}$.

iii. $1.5\ \mu m / 500\ nm = \mathbf{3\ fringes}$; the shift is $3\beta = 3 \times \lambda D/d = 3 \times 1.0\ mm = \mathbf{3.0\ mm}$.

MARKING SCHEME

- ✓ The pattern shifts towards the covered slit.
- ✓ Extra optical path $(\mu - 1)t = 1.5\ \mu m$.
- ✓ 3 fringes.
- ✓ 3.0 mm.

4 Read the data

ANSWER A · 3

i. β/D is the same each time, 1.96 mm per meter: $\beta \propto \mathbf{D}$.

ii. $\lambda = (\beta/D) \times d = 1.96 \times 10^{-3} \times 0.30 \times 10^{-3} = \mathbf{5.9 \times 10^{-7}\ m}$ (588 nm).

MARKING SCHEME

- ✓ $\beta \propto D$ (β/D constant).
- ✓ $\lambda = (\beta/D)\, d$.
- ✓ $\lambda = 588$ nm.

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5 A real setting

ANSWER A · 3

$\lambda = 340/680 = 0.50$ m. Quietest first where the path difference is $\lambda/2$: d sin $\theta = 0.25$ m, sin $\theta = 0.25/1.5 = 0.167$, $\theta = 9.6°$.

The distance along her line: x = 4.0 tan 9.6° ≈ **0.68 m** (d sin θ is only roughly right this close; an exact sum gives 0.69 m).

MARKING SCHEME

- ✓ $\lambda = 0.50$ m.
- ✓ d sin $\theta = \lambda/2$ gives $\theta = 9.6°$.
- ✓ x ≈ 0.68 m.

6 What if?

ANSWER HA · 3

At the center the paths are equal, but the waves now arrive in antiphase: the center is **dark**. Everywhere the bright and dark fringes swap: bright where the path difference is (n − ½)λ, dark where it is nλ. The fringe width is unchanged; the whole pattern shifts by half a fringe.

MARKING SCHEME

- ✓ The center is dark.
- ✓ Bright and dark fringes swap places.
- ✓ The fringe width stays the same (a shift of half a fringe).

7 Estimate it

ANSWER A · 3

n = d sin $\theta/\lambda \leq$ d/$\lambda = 2.0/0.55 = 3.6$. So n can be 0, 1, 2 or 3 on each side: **7 bright fringes** in all (the central one and three on each side).

MARKING SCHEME

- ✓ n ≤ d/$\lambda = 3.6$.
- ✓ n = 0 to 3 on each side.
- ✓ 7 bright fringes.

8 Correct the misconceptions

ANSWER U · 3

1. Energy isn't destroyed: it is moved from the dark fringes to the bright ones ($4I_0$ at the bright, 0 at the dark; the average is $2I_0$).
2. Two separate bulbs aren't coherent: the phase of their light changes at random, many times a second. Coherent sources come from one source, as the two slits do.
3. $\beta = \lambda$D/d: bringing the slits closer makes the fringes **wider**.

MARKING SCHEME

- ✓ Energy is moved to the bright fringes, not destroyed.
- ✓ Separate bulbs aren't coherent.
- ✓ A smaller d gives wider fringes.

9 Work backwards

ANSWER A · 2

The second dark fringe is at $x = \frac{3\lambda D}{2d}$, so $\lambda = \frac{2xd}{3D} = \frac{2 \times 3.3 \times 10^{-3} \times 0.50 \times 10^{-3}}{3 \times 1.5} = \mathbf{7.3 \times 10^{-7}\ m}$ (733 nm).

MARKING SCHEME

- ✓ Second dark fringe at 3λD/2d.
- ✓ $\lambda = 733$ nm.

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10 Make your own

HA · 2

ANSWER

$d/D = \lambda/\beta = 550 \times 10^{-9} \div 2.0 \times 10^{-3} = 2.75 \times 10^{-4}$. For example **D = 1.0 m and d = 0.275 mm** (or D = 2.0 m and d = 0.55 mm).

MARKING SCHEME

✓ $d/D = \lambda/\beta = 2.75 \times 10^{-4}$.

✓ A suitable pair, e.g. D = 1.0 m, d = 0.275 mm.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	13	9	**28**

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