Unit 11 · Interference of Light

ANSWER KEY · FOR TEACHERS

Full marks 33

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

1 Key words

1. coherent sources
2. constructive interference
3. destructive interference
4. sustained interference
5. optical path
6. path difference
7. fringe width
8. superposition

Each carries 0.5 mark. K · 4

2 Label the diagram

1. θ
2. d sin θ
3. x
4. O

Each carries 0.5 mark. K · 2

3 Multiple choice

i. **a.** bright, since 3λ is a whole number of wavelengths — U · 1

A path difference of a whole number of wavelengths, $n\lambda$, means the waves arrive in phase: constructive interference.

ii. **b.** 2.6 mm — A · 1

$\beta = \lambda D/d = 650 \times 10^{-9} \times 1.6 \div 0.40 \times 10^{-3} = 2.6 \times 10^{-3}$ m.

iii. **b.** get narrower, by 1.33 times — U · 1

In water the wavelength is λ/μ, so $\beta = \lambda D/(\mu d)$ is 1.33 times smaller.

iv. **a.** bright, with a phase difference of 6π — A · 1

$\Delta x/\lambda = 1.62/0.540 = 3$, so $\varphi = 2\pi \times 3 = 6\pi$: in phase, bright.

v. **c.** $4I_0$ — K · 1

In phase the amplitudes add, 2a; the intensity goes as the amplitude squared, so it is $4I_0$ (and zero at the dark fringes).

4 Short answers

a. MARKING SCHEME — K · 2

- ✓ Any one, e.g. the two sources must be coherent (a constant phase difference).
- ✓ Any second, e.g. the same wavelength (monochromatic light); nearly equal amplitudes; narrow sources close together.

b. MARKING SCHEME — U · 2

- ✓ Reflections from the two surfaces interfere.
- ✓ The path difference depends on the thickness, so different colors are strengthened in different places.

c. MARKING SCHEME — A · 3

- ✓ $\beta = 2.2$ mm.
- ✓ Third dark fringe at 5.5 mm.
- ✓ Fourth bright fringe at 8.8 mm.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

5 Long answer

ANSWER U · 4

For a point P a distance x from the center O, the path difference between the waves from the two slits is $S_2P - S_1P = d \sin\theta \approx d \tan\theta = xd/D$, since θ is small.

P is bright when the path difference is a whole number of wavelengths: $xd/D = n\lambda$, so $x_n = \frac{n\lambda D}{d}$.

The next bright fringe is at $x_{n+1} = \frac{(n+1)\lambda D}{d}$.

Their separation, $\beta = x_{n+1} - x_n = \frac{\lambda D}{d}$, is the same for every n: the fringes are equally spaced.

MARKING SCHEME

- ✓ Path difference = xd/D.
- ✓ Bright when $xd/D = n\lambda$.
- ✓ $x_n = n\lambda D/d$.
- ✓ $\beta = \lambda D/d$, the same for every n.

6 Numerical problems

a. **ANSWER** A · 4

i. $\beta = 18.9/10 = \mathbf{1.89\ mm}$.

ii. $\lambda = \beta d/D = 1.89 \times 10^{-3} \times 0.50 \times 10^{-3} \div 1.5 = \mathbf{6.3 \times 10^{-7}\ m}$ (630 nm).

iii. $\beta \propto D$: $1.89 \times 2.0/1.5 = \mathbf{2.52\ mm}$.

iv. $\sin\theta = \lambda/d = 6.3 \times 10^{-7} \div 0.50 \times 10^{-3} = \mathbf{1.26 \times 10^{-3}\ rad}$.

MARKING SCHEME

- ✓ $\beta = 1.89$ mm.
- ✓ $\lambda = 630$ nm.
- ✓ $\beta = 2.52$ mm at 2.0 m.
- ✓ $\theta = 1.26 \times 10^{-3}$ rad.

b. **ANSWER** A · 4

i. $\beta_1 = 520 \times 10^{-9} \times 1.2 \div 0.40 \times 10^{-3} = \mathbf{1.56\ mm}$; $\beta_2 = 650 \times 10^{-9} \times 1.2 \div 0.40 \times 10^{-3} = \mathbf{1.95\ mm}$.

ii. They coincide where $n_1 \times 520 = n_2 \times 650$; the smallest whole numbers are $n_1 = 5$, $n_2 = 4$ (2600 nm). $x = 5 \times 1.56 = \mathbf{7.8\ mm}$.

MARKING SCHEME

- ✓ $\beta_1 = 1.56$ mm.
- ✓ $\beta_2 = 1.95$ mm.
- ✓ $n_1\lambda_1 = n_2\lambda_2$ gives $n_1 = 5$, $n_2 = 4$.
- ✓ x = 7.8 mm.

7 Think

ANSWER HA · 3

The fringes stay in the same places, since the path differences don't change. But the waves no longer cancel completely: at a dark fringe the amplitude is $a - a/2 = a/2$, not zero, so the dark fringes are no longer dark. At a bright fringe it is $a + a/2 = 1.5a$, less than 2a, so the bright fringes are dimmer. The pattern is less clear.

MARKING SCHEME

- ✓ The fringes stay in the same places.
- ✓ Dark fringes are no longer fully dark (amplitude a/2).
- ✓ Bright fringes are dimmer (1.5a instead of 2a): less contrast.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

8 Activity: Colors on an oil film

(not marked)

WHAT STUDENTS SHOULD FIND

Bands of color appear and shift as the film spreads. Light reflected from the top and bottom of the oil film interferes; at each thickness a different color meets in phase. As the film spreads it thins, so the colors move; where it becomes very thin the colors fade.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	9	8	13	3	**33**

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking