Wave Optics

Standard difficulty · 20 questions · 40 marks · Time: 38 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer 8 × 1 = 8 marks

1. In Young's double-slit experiment, λ = 430 nm, the slits are 1.5 mm apart and the screen is 2 m away. The fringe width is:

(a) 0.0573 mm **(b)** 5.73 mm **(c)** 1.15 mm **(d)** 0.573 mm

2. In a double-slit experiment the fringe width is 1.3 mm. The 5th dark fringe is at a distance from the central bright fringe of:

(a) 6.5 mm **(b)** 7.8 mm **(c)** 5.85 mm **(d)** 13 mm

3. The Brewster angle for light going from air into a medium of refractive index 1.5 is:

(a) $\tan^{-1}(4/3)$ **(b)** $\tan^{-1}(1.6)$ **(c)** 60° **(d)** $\tan^{-1}(1.5)$

4. Unpolarised light of intensity 44 W/m^2 passes through two polaroids whose axes are at 60°. The intensity that comes out is:

(a) 5.5 W/m^2 **(b)** 33 W/m^2 **(c)** 11 W/m^2 **(d)** 22 W/m^2

5. According to Huygens' principle, each point on a wavefront acts as:

(a) a sink of energy **(b)** a source of secondary wavelets
(c) a reflecting surface **(d)** a point of zero intensity

6. Light of wavelength 630 nm falls on a single slit 0.5 mm wide. The width of the central bright band on a screen 1 m away is:

(a) 2.52 mm **(b)** 0.252 mm **(c)** 1.26 mm **(d)** 5.04 mm

7. Light of wavelength 816 nm in air enters a medium of refractive index 3/2. Its wavelength inside is:

(a) 272 nm **(b)** 1,224 nm **(c)** 544 nm **(d)** 816 nm

8. Assertion (A): In a double-slit experiment with λ = 510 nm, d = 0.25 mm and D = 2 m, doubling the slit separation makes the fringe width 2.04 mm.
Reason (R): The fringe width is β = λD/d.

(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is not the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

Section B — Short answer 8 × 2 = 16 marks

9. In Young's experiment λ = 520 nm, d = 1.5 mm and D = 3 m. Find the fringe width and the distance of the 5th bright fringe from the centre.

10. A double-slit set-up gives fringes 2.68 mm wide in air. What is the fringe width when the whole apparatus is put in a liquid of refractive index 5/4?

11. Two coherent sources each give intensity 10 W/m^2 on a screen. Find the intensity at a point where the path difference is 3λ/2.

12. A single slit 0.25 mm wide is lit by light of wavelength 680 nm. Find the angle of the first minimum (in radians) and the width of the central maximum on a screen 2 m away.

13. Unpolarised light of intensity 80 W/m^2 passes through three polaroids. The second is at 60° to the first and the third at 60° to the second. Find the intensity that comes out.

14. Light reflected from a surface of refractive index 5/3 is completely polarised. Find the angle of incidence and the angle of refraction.

15. In a double-slit pattern with fringe width 1.1 mm, find the distance between the 1st bright fringe and the 2nd dark fringe on the same side of the centre.

16. Light of frequency 4×10^{14} Hz goes from air into glass of refractive index 4/3. Find its wavelength in air and in the glass, and its frequency in the glass.

Section C — Word problems — 4 × 4 = 16 marks

17. A double-slit experiment uses light containing wavelengths 400 nm and 600 nm, with d = 2 mm and D = 3 m. Find the fringe width for each, and the least distance from the centre at which bright fringes of both wavelengths coincide.

18. Unpolarised light of intensity 112 W/m^2 falls on two crossed polaroids, so no light comes through. A third polaroid is placed between them with its axis at 45° to the first. Find the intensity that comes out now.

19. Light of wavelength 440 nm passes through two slits, each 0.2 mm wide and 1 mm apart, onto a screen 1 m away. Find the fringe width of the double-slit pattern, the width of the central diffraction band, and how many double-slit fringes fit inside that band.

20. Unpolarised light of intensity 32 W/m^2 is reflected from glass of refractive index 5/4 at the Brewster angle, and the reflected beam then passes through a polaroid. Find the Brewster angle and the angle of refraction. At what angle between the polaroid axis and the plane of polarisation does no light pass?

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Answer key

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Q	Answer	Working
1	**(d) 0.573 mm**	$\beta = \lambda D/d$
2	**(c) 5.85 mm**	$y = (n - ½)\beta$
3	**(d) $\tan^{-1}(1.5)$**	$\tan i_B = n$
4	**(a) 5.5 W/m^2**	the first polaroid passes half; then $I = I_1 \cos^2\theta$
5	**(b) a source of secondary wavelets**	—
6	**(a) 2.52 mm**	width $= 2\lambda D/a$
7	**(c) 544 nm**	$\lambda = \lambda_0/n$; the frequency does not change
8	**(a) Both A and R are true, and R is the correct explanation of A.**	A is true: $\beta = \lambda D/d = 4.08$ mm, and doubling d halves it to 2.04 mm. R is true and explains A.
9	**1.04 mm; 5.2 mm**	$\beta = \lambda D/d$; $y = n\beta$
10	**2.144 mm**	λ falls to λ/n, and so does β
11	**0 W/m^2**	$I = 4I_0 \cos^2(\varphi/2)$, $\varphi = 2\pi \times$ (path difference)$/\lambda$
12	**2.72 × 10^{-3} rad; 10.88 mm**	$a \sin\theta = \lambda$; width $= 2\lambda D/a$
13	**2.5 W/m^2**	$80/2 \times \cos^2 60° \times \cos^2 60°$
14	**$\tan^{-1}(5/3)$; $\tan^{-1}(3/5)$**	$\tan i_B = n$, and the reflected and refracted rays are at 90°
15	**0.55 mm**	1β and $(2 - ½)\beta$
16	**750 nm; 562.5 nm; 4 × 10^{14} Hz**	$\lambda = c/f$; $\lambda_{glass} = \lambda/n$
17	**0.6 mm and 0.9 mm; 1.8 mm (the 3rd bright fringe of 400 nm meets the 2nd of 600 nm)**	$n_1 \times 400 = n_2 \times 600$
18	**14 W/m^2**	$112/2 \times \cos^2 45° \times \cos^2 45°$
19	**0.44 mm; 4.4 mm; 10**	$\beta = \lambda D/d$; band width $= 2\lambda D/a$; number $= 2d/a$
20	**$\tan^{-1}(5/4)$; $\tan^{-1}(4/5)$; 90°**	$\tan i_B = n$; $i_B + r = 90°$; Malus: $I = I_0 \cos^2\theta$

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