INTERNATIONAL BACCALAUREATE · IB DIPLOMA · PHYSICS · SL • EXERCISE SHEET

10.2 Wave phenomena (full C.3, SL)

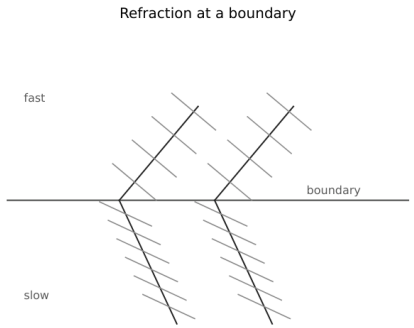
Name: _____ Class: _____ Date: _____ **Total: 24 marks**

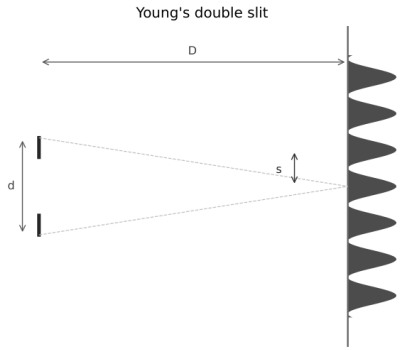
KEY WORDS wavefront • refractive index • total internal reflection • coherent sources • diffraction

Objective

Practise the full guide C.3 toolkit at standard level: wavefronts and rays, reflection, refraction and transmission at boundaries, Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$, critical angle and total internal reflection, diffraction, superposition with path differences $n\lambda$ and $(n+\frac{1}{2})\lambda$, coherence, and Young's double-slit relation $s = \lambda D/d$. Original practice; not an official IB paper.

1 Key knowledge and worked examples





■ **The C.3 equation set (SL)**

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \sin\theta_c = \frac{n_2}{n_1} \qquad s = \frac{\lambda D}{d}$$

Path difference from two coherent sources: $n\lambda$ builds a maximum, $(n+\frac{1}{2})\lambda$ gives a minimum. Refraction bends a ray toward the normal entering a slower (higher-n) medium; frequency stays fixed, wavelength shortens with speed.

■ **Worked example: reading the double-slit set-up**

Slits $d = 0.20$ mm apart, screen $D = 2.4$ m away, 12 bright fringes across 55 mm – that is 11 gaps, so $s = 5.0$ mm. Then $\lambda = sd/D = (5.0 \times 10^{-3} \times 0.20 \times 10^{-3})/2.4 = 4.2 \times 10^{-7}$ m. Two habits: count fringe gaps, not fringes, and check the wavelength lands where the colour says it should.

2 Practice

2.1 State what a wavefront is, and state the geometric relationship between a wavefront and a ray. [2]

2.2 A ray travels from air ($n = 1.0$) into water ($n = 1.3$) at 50° to the normal. Calculate the angle of refraction. [3]

2.3 State the two conditions required for total internal reflection. [2]

2.4 Two coherent sources emit in phase with wavelength 0.60 m. A point is 2.00 m from one source and 2.30 m from the other. Determine whether the interference there is constructive or destructive. [2]

3 Exam-style questions

3.1 A glass block has refractive index 1.5 and sits in air. Calculate the critical angle for the glass–air boundary, and calculate the refraction angle for a ray inside the glass hitting that boundary at 30° to the normal. [4]

3.2 Explain why sound heard through a doorway spreads around the frame while light through the same doorway appears to travel in straight lines. [3]

3.3 In a double-slit experiment, green light of wavelength 5.2×10^{-7} m gives fringes 4.0 mm apart with the screen 2.0 m from the slits. Calculate the slit separation, and state the effect on the fringe separation of moving the screen to 4.0 m. [4]

3.4 Light of wavelength 6.0×10^{-7} m passes through two slits 0.30 mm apart onto a screen 1.5 m away. Calculate the fringe separation, and explain why the two slits must be coherent for fringes to appear. [4]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 A line joining points that are in phase (one wavelength apart); a ray shows the direction of energy travel and is perpendicular to the wavefronts.

2.2 $\sin\theta_2 = (n_1/n_2)\sin\theta_1 = (1.0/1.3)\sin 50° = 0.589$; $\theta_2 = 36°$.

2.3 The wave must travel from a slower (higher refractive index) medium toward a faster one, and the angle of incidence must exceed the critical angle.

2.4 Path difference $= 2.30 - 2.00 = 0.30$ m $= \frac{1}{2}\lambda$ – half a wavelength out of step, so destructive: a minimum.

3.1 $\sin\theta_c = n_2/n_1 = 1.0/1.5 = 0.667$, so $\theta_c = 42°$; $30° < 42°$, so the ray escapes: $\sin\theta_2 = 1.5\sin 30° = 0.75$, $\theta_2 = 49°$.

3.2 Diffraction spread depends on the ratio of wavelength to aperture; sound has metre-scale wavelengths comparable with a doorway, so it diffracts strongly around the frame; light's wavelength (hundreds of nanometres) is tiny beside the opening, so its spreading is negligible.

3.3 $d = \lambda D/s = (5.2\times10^{-7}\times 2.0)/4.0\times10^{-3} = 2.6\times10^{-4}$ m $= 0.26$ mm; $s \propto D$ at fixed λ and d, so the fringes double to 8.0 mm.

3.4 $s = \lambda D/d = (6.0\times10^{-7}\times 1.5)/3.0\times10^{-4} = 3.0\times10^{-3}$ m $= 3.0$ mm; coherence – a constant phase difference and equal frequencies – keeps the same points of the screen always receiving crest-with-crest or crest-with-trough, so the pattern is steady rather than washing out.