

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

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

2.5 $\sin \theta = \lambda/b = (5.0 \times 10^{-7})/(5.0 \times 10^{-5}) = 1.0 \times 10^{-2}$, so $\theta = 0.57^\circ$; widening the slit narrows the pattern – $\theta \propto 1/b$.

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

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 $d = \lambda D/s = (5.2 \times 10^{-7} \times 2.0)/4.0 \times 10^{-3} = 2.6 \times 10^{-4} \text{ m} = 0.26 \text{ mm}$; $s \propto D$ at fixed λ and d , so the fringes double to 8.0 mm.

3.4 $s = \lambda D/d = (6.0 \times 10^{-7} \times 1.5)/3.0 \times 10^{-4} = 3.0 \times 10^{-3} \text{ m} = 3.0 \text{ mm}$; 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.

3.5 $d = 1.0 \times 10^{-3}/500 = 2.0 \times 10^{-6} \text{ m}$; orders at $\sin \theta = 0.30, 0.60, 0.90$ – $17^\circ, 37^\circ, 64^\circ$; order 4 needs $\sin \theta = 1.2$, impossible, so exactly three orders are visible; many slits contribute to each maximum, making grating maxima brighter and far narrower than two-slit fringes.