C.3 Wave phenomena

Practice Worksheet — name: ________________________ date: _____________

FORMULAS FOR THIS TOPIC

SNELL'S LAW $\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$ REFRACTIVE INDEX $n = \frac{c}{v}$ CONSTRUCTIVE INTERFERENCE $\text{path difference} = n\lambda$

DESTRUCTIVE INTERFERENCE $\text{path difference} = \left(n + \frac{1}{2}\right)\lambda$ DOUBLE-SLIT FRINGE SPACING $s = \frac{\lambda D}{d}$

SINGLE-SLIT FIRST MINIMUM (HL) $\theta = \frac{\lambda}{b}$ DIFFRACTION GRATING MAXIMA (HL) $n\lambda = d\sin\theta$

SECTION A — MULTIPLE CHOICE

A1. Light travels from glass ($n = 1.5$) towards air. The critical angle is approximately:

- A 30°
- B 42°
- C 48°
- D 60°

A2. In a double-slit experiment, the slit separation is doubled and the screen distance halved. The fringe spacing becomes:

- A Four times larger
- B Unchanged
- C A quarter of the original
- D Half the original

A3. Sound diffracts around a doorway much more than light does because:

- A Sound travels more slowly than light
- B Sound is longitudinal and light is transverse
- C Sound's wavelength is comparable to the width of the doorway
- D Sound has more energy than light

SECTION B — SHORT ANSWER

B1. In a Young's double-slit experiment, slits 0.40 mm apart produce fringes 3.2 mm apart on a screen 2.0 m away. Calculate the wavelength of the light. [3 marks]

B2. Explain why two separate lamps cannot produce a visible interference pattern, but two slits illuminated by one lamp can. [3 marks]

B3. Monochromatic light of wavelength 600 nm falls on a diffraction grating with 500 lines per mm. Determine how many orders of maxima can be observed. [4 marks]

ANSWER KEY

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Section A

A1: 42° — At the critical angle the refracted ray grazes the surface: $\sin\theta_c = n_2/n_1 = 1/1.5 = 0.667$, so $\theta_c \approx 41.8^\circ$. Beyond this, total internal reflection traps the light — the principle of optical fibres.

A2: A quarter of the original — $s = \lambda D/d$: halving D halves s, doubling d halves it again — net factor $\frac{1}{4}$. Fringe spacing grows with wavelength and screen distance but shrinks with slit separation.

A3: Sound's wavelength is comparable to the width of the doorway — Diffraction is significant when $\lambda \sim b$. Audible sound has wavelengths from centimetres to metres — doorway-sized — while visible light's half-micrometre wavelength is a million times smaller than the gap.

Section B

B1: Rearranging $s = \lambda D/d$: $\lambda = sd/D = (3.2 \times 10^{-3})(0.40 \times 10^{-3})/2.0 = 6.4 \times 10^{-7}\ \mathrm{m} = 640\ \mathrm{nm}$ — red light.

B2: Interference requires coherence — a constant phase relationship. Independent lamps emit light in random, uncorrelated bursts, so the phase difference changes billions of times per second and any pattern averages away. Two slits fed by the same wavefront derive from a single source, so their phase difference is fixed and stable fringes form.

B3: Slit spacing $d = 1/(500 \times 10^3) = 2.0 \times 10^{-6}$ m. Maximum order when $\sin\theta = 1$: $n_{max} = d/\lambda = 2.0 \times 10^{-6}/6.0 \times 10^{-7} = 3.3$, so $n = 3$ is the highest complete order. Observable: $n = 0, \pm1, \pm2, \pm3$ — seven maxima in total.