AQA AS Refraction, Total Internal Reflection and Optical Fibres worksheet

35–40 minutes independent practice + 15–20 minutes review | *38 marks*

Specification points covered

• 3.3.2.3(a) Refractive index $n = c/c_s$. • 3.3.2.3(b) Air has refractive index approximately 1. • 3.3.2.3(c) Refraction at a plane boundary and Snell's law. • 3.3.2.3(d) Critical angle and total internal reflection.	• 3.3.2.3(e) Optical-fibre core and cladding. • 3.3.2.3(f) Step-index optical fibres. • 3.3.2.3(g) Material and modal dispersion. • 3.3.2.3(h) Pulse broadening and absorption.

Subsea cable repair

An engineering team must diagnose and replace an 80 km optical link serving an offshore research station. Connect the ray model to measurable signal quality: travel time, attenuation and pulse broadening.

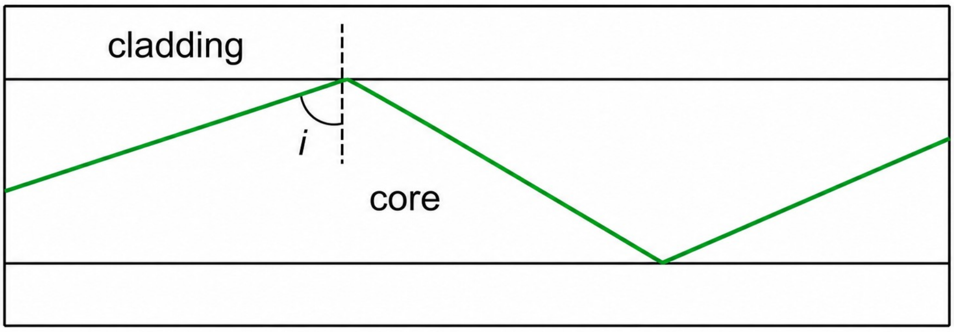
1. Entering the fibre

1. A subsea data cable uses monochromatic light of vacuum wavelength 1.55 μm in a glass core of refractive index 1.50. Calculate (a) the speed of the light in the core, (b) its frequency and (c) its wavelength in the core. [3 marks]

2. A test ray enters the glass core from air at an angle of incidence of 35.0°. Calculate the angle of refraction in the core. [2 marks]

2. Confining the ray

3. The figure shows a ray in the step-index fibre. State both conditions needed for total internal reflection at the core–cladding boundary and explain why the refractive index of the core must be greater than that of the cladding. **[3 marks]**



4. The refractive indices of the core and cladding are 1.50 and 1.47 respectively. Calculate the critical angle at their boundary. **[2 marks]**

5. Hence determine the greatest angle that a ray inside the core can make with the fibre axis and still undergo total internal reflection. **[2 marks]**

3. Sending a data pulse

6. The repaired section is 80.0 km long. Calculate the travel time of a light pulse through it. Assume the light travels along the fibre axis and the core refractive index is 1.50. [2 marks]

7. An input pulse has duration 3.0 ns and the received pulse has duration 8.0 ns. State what is meant by pulse broadening and explain why it limits the maximum data rate. [3 marks]

8. Explain how modal dispersion causes pulse broadening in a step-index fibre and why reducing the difference between the core and cladding refractive indices reduces this effect. [3 marks]

4. Diagnosing signal quality

9. Explain how material dispersion broadens a pulse. State one change to the source that reduces material dispersion. [3 marks]

10. The optical power falls as the pulse travels along the cable. Explain what is meant by absorption and why an amplifier or repeater may be needed on a long link. [2 marks]

11. Three replacement fibres are tested over 80.0 km. Fibre A: attenuation 0.20 dB km^{-1}, modal broadening 0.050 ns km^{-1}. Fibre B: 0.28 dB km^{-1}, 0.015 ns km^{-1}. Fibre C: 0.16 dB km^{-1}, 0.090 ns km^{-1}. The link requires total attenuation no greater than 20 dB and modal broadening no greater than 5.0 ns. Calculate both totals for each fibre and select the only suitable fibre. [4 marks]

5. Commissioning the link

12. A refractometer sends light from glass of refractive index 1.52 into a liquid. The angle of incidence in the glass is 50.0° and the angle of refraction in the liquid is 68.0°. Calculate the refractive index of the liquid. **[3 marks]**

13. After installation, the received pulses are both weaker and wider than the transmitted pulses. Write a structured diagnosis of the link. Distinguish absorption from pulse broadening, identify plausible causes involving connectors, bends, modal dispersion and material dispersion, and describe measurements or changes that would test and correct the faults. **[6 marks]**

Review and improve

- □ I measure every optical angle from the normal.
- □ I separate attenuation from pulse broadening.
- □ I test a fibre choice against every stated engineering limit.