InkPhysics

QUESTION WORKBOOK

Refraction and total internal reflection

Waves · Year 12

AQA 3.3.2.3 · OCR A 4.4.1(f)(i), 4.4.2(d)(i), 4.4.2(e)

18 questions · 52 marks

NAVY SCREEN EDITION

inkphysics.co.uk/physics/ · youtube.com/@InkPhysics

SECTION A · Warm-up

A1 Define the refractive index of a material in terms of the speed of light. [2]

A2 Light travels at 2.0×10^{8} m s^{-1} in a glass block. Calculate the refractive index of the glass. [2]

A3 State the two conditions required for total internal reflection to occur. [2]

A4 A ray of light passes from air into a glass block. State what happens, if anything, to the speed, the frequency and the wavelength of the light. [2]

A5 Explain why light travelling from air into glass can never be totally internally reflected at the boundary, however large the angle of incidence. [2]

SECTION B · Standard

B1 A ray of light passes from air into glass of refractive index 1.5 at an angle of incidence of 40°. Calculate the angle of refraction. [3]

B2 Calculate the critical angle for a glass–air boundary where the glass has a refractive index of 1.5. [2]

B3 Light of wavelength 600 nm in air enters glass of refractive index 1.5. Calculate its wavelength and speed in the glass. [3]

B4 A ray of light travels from water (refractive index 1.33) into air, meeting the surface at an angle of incidence of 30° in the water. Calculate the angle of refraction in the air. [3]

B5 A ray of sunlight strikes the flat surface of a pond at 25° to the water surface. The refractive index of the water is 1.33. Calculate the angle of refraction in the water. [3]

B6 A ray of light passes from crown glass of refractive index 1.52 into flint glass of refractive index 1.66. The angle of incidence at the boundary is 50°. Calculate the angle of refraction, and state which way the ray bends. [3]

B7 State what is meant by modal dispersion in a step-index optical fibre, and give one design feature that reduces it. [2]

SECTION C · Stretch

C1 An optical fibre has a core of refractive index 1.50 and a cladding of refractive index 1.40. Calculate the critical angle at the core–cladding boundary. [3]

C2 A ray inside a glass block (refractive index 1.5) strikes a face at an angle of incidence of 45°. Deduce whether the ray is totally internally reflected or refracted out of the block. [3]

C3 Describe the structure of a step-index optical fibre and state the purpose of the cladding. [3]

C4 A manufacturer is designing a step-index optical fibre with a core of refractive index 1.52. To limit modal dispersion, the critical angle at the core–cladding boundary must be at least 80°. Three cladding glasses are available: P (refractive index 1.38), Q (refractive index 1.45) and R (refractive index 1.50). Deduce which cladding the manufacturer should choose. [4]

C5 A straight optical fibre is 15 km long and its core has a refractive index of 1.48. The speed of light in a vacuum is 3.0×10^8 m s^{-1}. Show that light travels along the core at about 2×10^8 m s^{-1}. Go on to calculate the minimum time for a light pulse to travel the length of the fibre. [4]

C6 A step-index optical fibre carries digital data as short pulses of light. Explain the two causes of pulse broadening in the fibre, state how the design of the fibre and the choice of light source reduce each one, and explain why pulse broadening limits the rate at which data can be sent. [6]