ICSE CLASS 10 · PHYSICS

Chapter 4 : REFRACTION OF LIGHT AT PLANE SURFACES

STEP-BY-STEP SOLUTIONS & MARKING SCHEME (40 MARKS)

Maximum Marks: 40 · Section A (20) compulsory · Section B: any two of three questions (2 × 10 = 20) · $c = 3 \times 10^8$ m s^{-1}

Marks for each step are shown in square brackets on the right. Rays added in the solution diagrams are drawn in red.

SECTION A (20 Marks)

Question 1 — Multiple choice [8 marks, 1 mark each]

No.	Answer	Reason
(i)	**(b)** c ÷ V	By definition μ = speed of light in vacuum ÷ speed in the medium = c ÷ V.
(ii)	**(d)** its frequency	The frequency depends on the source and stays constant; speed and wavelength decrease and (for oblique incidence) the direction changes.
(iii)	**(a)** 42°	sin C = 1 ÷ μ = 1 ÷ 1.5 = 2/3, so C ≈ 42°; for i > C the ray is totally reflected.
(iv)	**(c)** refraction	Light from the coin bends away from the normal on passing from water to air (refraction), so the coin seems raised.
(v)	**(c)** Both (A) and (R) are true, and (R) is the correct explanation for (A).	Both are true: a prism reflects 100% of the light (no loss), whereas a plane mirror reflects only part of it; (R) explains (A).
(vi)	**(b)** 180°	The ray enters undeviated, strikes each of the two 45° faces at 45° > 42° and is totally reflected twice (90° at each), so it returns parallel with total deviation 180°.
(vii)	**(d)** is deviated more	μ is greatest for violet, so violet slows down most and is bent most: $\delta_{violet} > \delta_{red}$.
(viii)	**(a)** 9 cm	Apparent depth = real depth ÷ μ = 12 ÷ (4/3) = 9 cm.

Question 2 [6 marks]

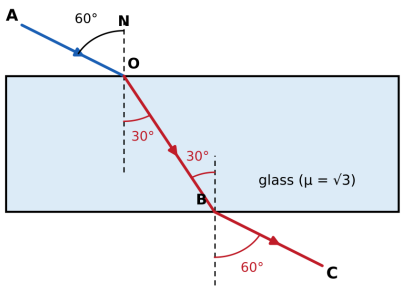
(a) **Snell's law:** the incident ray, the refracted ray and the normal at the point of incidence lie in the same plane, and the ratio sin i ÷ sin r is constant for a given pair of media (= refractive index of the second medium with respect to the first). [1] **[2]**

Refractive index of glass = 1.5 means the speed of light in vacuum (air) is **1.5 times** its speed in glass. [1]

(b) (i) sin i ÷ sin r = μ → sin r = sin 60° ÷ √3 = 0.866 ÷ 1.732 = 0.5 → **r = 30°**. [1] **[3]**

(ii) The two faces are parallel, so the angle of incidence at the second face = r = 30°. By reversibility the angle of emergence **e = 60° = i**; the emergent ray is **parallel to the incident ray AO** but laterally displaced. [1]

(iii) V = c ÷ μ = $3 \times 10^8 \div \sqrt{3}$ = **1.73×10^8 m s^{-1}**. [1]



Solution to Q2(b)

(c) **Violet**: it has the largest refractive index (μ = c ÷ V), so its speed in glass is the least. [1] **[1]**

Question 3 [6 marks]

(a) $\lambda = 6000$ Å $= 6 \times 10^{-7}$ m. **[3]**

(i) $f = c \div \lambda = 3 \times 10^8 \div 6 \times 10^{-7} =$ **5×10^{14} Hz**. [1]

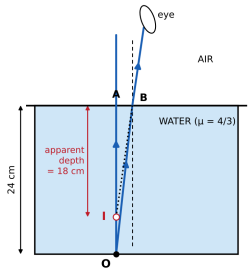
(ii) $V = c \div \mu = 3 \times 10^8 \div 1.5 =$ **2×10^8 m s^{-1}**. [1]

(iii) $\lambda' = \lambda \div \mu = 6000 \div 1.5 =$ **4000 Å** ($= 4 \times 10^{-7}$ m; check: $V \div f = 2 \times 10^8 \div 5 \times 10^{14} = 4 \times 10^{-7}$ m). [1]

(b) (i) Light going from water (denser) to air (rarer) bends **away from the normal** at B, so the refracted ray BC appears to come from a point I above O (the virtual image). [1] **[3]**

(ii) Apparent depth = real depth $\div \mu = 24 \div (4/3) =$ **18 cm**. [1]

(iii) Shift = real depth − apparent depth $= 24 - 18 =$ **6 cm**. [1]



Solution to Q3(b)

SECTION B (20 Marks) — any two questions

Question 4 [10 marks]

(a) (i) $\delta = (i_1 + i_2) - A = (40° + 62°) - 60° =$ **42°**. [1] **[3]**

(ii) At minimum deviation $i_1 = i_2 = i$: $\delta_{min} = 2i - A \rightarrow 38° = 2i - 60° \rightarrow$ **$i = 49°$**. [1]

(iii) Since $r_1 = r_2 = A \div 2 = 30°$ the refracted ray inside the prism is **parallel to the base BC**. [1]

(b) **Critical angle** is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90°. [1] **[3]**

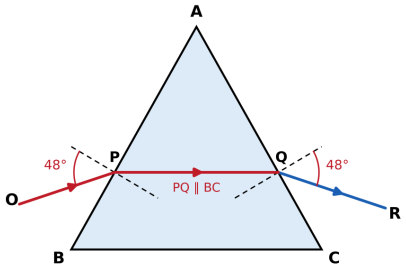
Ray from the denser medium to air at i = C, r = 90°: ${}_g\mu_a = \sin C \div \sin 90° = \sin C$. [1]

By reversibility ${}_a\mu_g = 1 \div {}_g\mu_a$, so **$\mu = 1 \div \sin C$**. [1]

(c) (i) At minimum deviation PQ is parallel to BC; draw the normals at P and Q and OP such that the angle of incidence at P equals the angle of emergence 48° (see the red rays in the figure). [2] **[4]**

(ii) Angle of incidence at P = $i_1 = i_2 =$ **48°**; **PQ ∥ BC**. [1]

(iii) $\delta_{min} = 2i - A = 2 \times 48° - 60° =$ **36°**. [1]



Solution to Q4(c)

Question 5 [10 marks]

(a) (i) $\mu = 1 \div \sin C = 1 \div \sin 30° = 1 \div 0.5 = \mathbf{2}$. [1] **[3]**

(ii) $V = c \div \mu = 3 \times 10^8 \div 2 = \mathbf{1.5 \times 10^8\ m\ s^{-1}}$. [1]

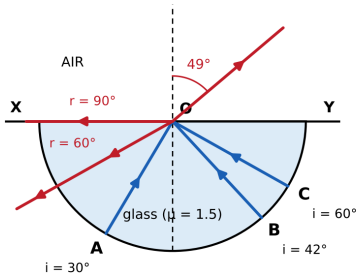
(iii) The ray travels from the denser medium to air and 40° > C = 30°, so it undergoes **total internal reflection** (no refraction). [1]

(b) Ray A (i = 30° < 42°): refracted into air and bends away from the normal: $\sin r = 1.5 \times \sin 30° = 0.75 \rightarrow r \approx \mathbf{49°}$. [½] **[3]**

Ray B (i = 42° = C): refracted along the surface XY, r = **90°**. [½]

Ray C (i = 60° > C): **totally reflected** at O with angle of reflection 60°, then leaves the curved surface along the radius. [1]

(ii) Phenomenon for ray C: **total internal reflection**. The rays travel along the radius, so they meet the curved surface normally (i = 0°) and pass undeviated. [1]



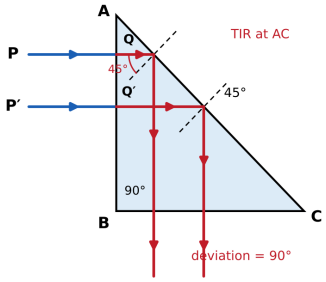
Solution to Q5(b)

(c) (i) At AB the incidence is normal (0°). The angle of incidence at AC = **45°** (the angles of the prism are 45°, 45°, 90°). [1] **[4]**

(ii) **Yes**: 45° is greater than the critical angle 42° and the light travels from glass to air. [1]

(iii) Each ray is reflected through 90° at AC, travels down, strikes BC normally and goes out undeviated. Total deviation = **90°**. [1]

(iv) **Periscope** (also prismatic binoculars). [1]



Solution to Q5(c)

Question 6 [10 marks]

(a) (i) Apparent thickness = real thickness ÷ μ = 12 ÷ 1.5 = **8 cm**. [1] **[3]**

(ii) Shift = 12 − 8 = **4 cm**. [1]

(iii) **Violet**: it has the largest μ, so its apparent depth is least and the shift is maximum. [1]

(b) Any three (1 mark each): **[3]**

• TIR occurs only when light goes from a denser to a rarer medium at an angle greater than the critical angle; mirror reflection occurs at any angle and from any medium.

• In TIR the entire light is reflected; a plane mirror reflects only part of it (the rest is refracted and absorbed).

• In TIR there is no loss of energy; with a mirror there is some loss.

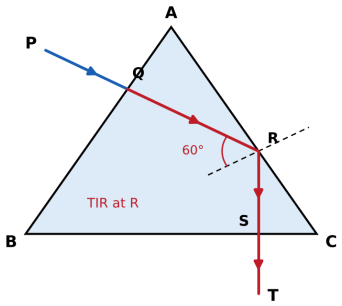
• The image in TIR stays equally bright; the silvering of a mirror deteriorates with time and the image becomes faint.

(c) (i) The ray PQ meets AB normally and goes straight to AC; the angle between PQ and AC is 30°, so the angle of incidence at AC = **60°**. [1] **[4]**

(ii) **Yes**, 60° > critical angle 42°, so total internal reflection occurs at R. [1]

(iii) The reflected ray RS moves vertically downwards, falls normally on BC (i = 0°) and passes undeviated as ST. [1]

(iv) The ray has turned through **60°** towards the base from its original direction. [1]



Solution to Q6(c)

Marks summary	
Section A: Q1 (8) + Q2 (2 + 3 + 1 = 6) + Q3 (3 + 3 = 6)	**20**
Section B: any two of Q4 – Q6 (10 marks each)	**20**
Total	**40**