

Mark Scheme Refraction Past Paper Questions Jan 2002 to Jan 2009

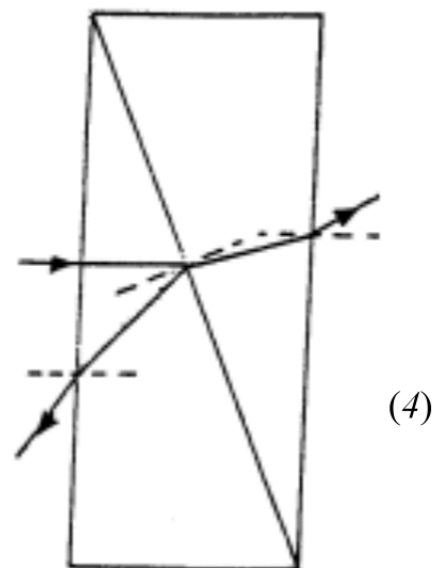
NOTE : Jan 2009 onwards are new spec'

| Question 6 | | |
|--------------|--|-----------|
| (a) (i) | (refractive index of water = $1/\sin 49.0$) = 1.33 (not 1.3 or 1.325) ✓ | 4 |
| (ii) | ray P shown in the air to right of vertical ✓ refracted away from the normal in the correct direction ✓ correct partial reflection shown ✓ | |
| (b) (i) | critical angle for water-air boundary = 49.0° or angle of (incidence of) Q is θ_c ✓ | 6 |
| (ii) | the angle of incidence (of R) exceeds the critical angle ✓ figure 6 shows that R undergoes TIR at water surface and strikes the glass side ✓ angle of incidence at glass side = 30° ✓ R enters the glass and refracts towards the normal ✓ because $n_g > n_w$ ✓ (or water is optically less dense than glass) (calculates angle = 26.2° gets last two marks) | |
| Total | | 10 |

Q6 Jan 2009

4(a) Ray diagram to show:

- (i) refraction towards normal at boundary ✓
emerging ray refracted away from normal ✓
- (ii) reflection at boundary with $i \approx r$ ✓
emerging ray refracted away from normal ✓



(b)(i) 20° ✓

(ii) ${}_1n_2 = \frac{n_2}{n_1} = \frac{\sin \theta_1}{\sin \theta_2}$ ✓

$\frac{1.60}{1.40} = \frac{\sin 20^\circ}{\sin \theta_2}$ ✓

$\theta_2 = 17(.4)^\circ$ ✓

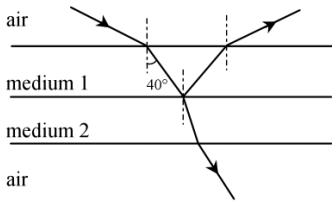
Q4 Jan 2002

- (c) ($\sin \theta_c = 1/n$ gives) $\sin \theta_c = 1/1.60$ ✓
 $\theta_c = 38.7^\circ$ ✓

(2)
(10)

Q3 Jun 2002

3(a)



- (i) incident angle $> 40^\circ$ ✓
 angle of refraction into medium 2 $< 40^\circ$ ✓
 emergent ray with correct refraction ✓

- (ii) reflection at boundary between media with $i \approx r$ ✓
 (hence) emergent ray at approximately same angle as incident ray
 and showing correct refraction ✓

max(4)

(b)(i) (use of ${}_1n_2 = \frac{\sin \theta_1}{\sin \theta_2}$ gives) $1.35 = \frac{\sin \theta_1}{\sin 40}$ ✓
 $\theta_1 = 60(2)^\circ$ ✓

(ii) (use of ${}_1n_2 = \frac{n_2}{n_1} = \frac{\sin \theta_1}{\sin \theta_2}$ gives) $\frac{1.65}{1.35} = \frac{\sin 40}{\sin \theta_2}$ ✓ ✓
 $\theta = 31.7^\circ$ ✓

(5)

- (c) (total internal reflection) only occurs when light goes
 from a higher to a lower refractive index
 [or goes from a more dense to a less dense medium/material] ✓

(1)
 (10)

7

Q7 Jan 2003

- (a)(i) θ_c marked ✓

(a)(ii) $\sin \theta_c = \frac{1}{n}$ ✓ $\left(= \frac{1}{1.55} \right)$
 $\theta_c = 40.2^\circ$ ✓

(3)

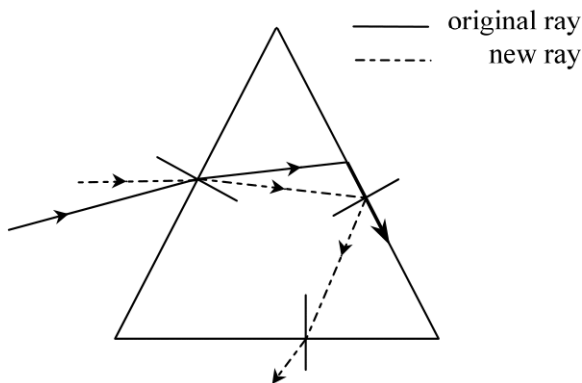
(b) $n = \frac{\sin \theta_1}{\sin \theta_2}$ ✓

$(\theta_2 = 90 - 75.2 = 14.8^\circ)$

$\theta_1 (= \sin^{-1}\{1.55 \sin 14.8\}) = 23.3^\circ$ ✓

(2)

(c)



- correct refraction at first surface ✓
 total internal refraction at second surface ✓
 correct refraction at third surface ✓

(3)
 (8)

5

(a)(i) (use of $n = \frac{c_1}{c_2}$ gives) $c_{\text{glass}} \left(= \frac{3.00 \times 10^8}{1.45} \right) = 2.07 \times 10^8 \text{ m s}^{-1} \checkmark$

Q5 Jun 2003

(a)(ii) use of $\frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2} \checkmark$

$$c_{\text{liquid}} = \frac{2.07 \times 10^8 \times \sin 29.2^\circ}{\sin 26.6^\circ} = 2.26 \times 10^8 \text{ m s}^{-1} \checkmark \quad (3)$$

(allow C.E. for values of c_{glass} from (i))

(b) use of ${}_1n_2 = \frac{c_1}{c_2}$ and ${}_1n_2 = \frac{n_2}{n_1} \checkmark$

$$\text{to give } n_{\text{liquid}} = \frac{1.45 \times 2.07 \times 10^8}{2.26 \times 10^8} = 1.33 \checkmark$$

$$\left[\text{or } n_l = \frac{c_1}{c_{\text{liquid}}} = \frac{3 \times 10^8}{2.26 \times 10^8} = 1.33 \right] \text{ (allow C.E. for value of } c_{\text{liquid}} \text{)}$$

[or use ${}_1n_2 = \frac{\sin \theta_1}{\sin \theta_2}$ and ${}_1n_2 = \frac{n_2}{n_1}$ to give correct answer] (2)

- (c) diagram to show :
total internal reflection on the vertical surface \checkmark
refraction at bottom surface with angle in air greater
than that in the liquid (29.2°) \checkmark (2)

(7)

3

- (a)(i) diagram to show: refraction towards normal on entry \checkmark
total internal reflection shown along fibre \checkmark
refraction away from normal on leaving glass \checkmark

- (ii) speed of light decreases on entry into glass and increases on leaving \checkmark (4)

(b)(i) (use of $\sin \theta_c = \frac{1}{n}$ gives) $\sin \theta_c = \frac{1}{1.57} \checkmark$
 $\theta_c = 39.6^\circ \checkmark$

Q3 Jan 2004

(ii) ${}_1n_2 \left(= \frac{n_2}{n_1} \right) = \frac{1.57}{1.47} \checkmark \text{ (= 1.07)}$

$$\sin \theta_c = \frac{1}{1.07} \quad \checkmark$$

$$\theta_c = 69.4^\circ \quad \checkmark$$

- (iii) to protect the core surface
[or to prevent cross-over] \checkmark

(6)
(10)

4

Q4 Jun 2004

- (a)(i) (angle) F \checkmark

- (ii) angle D is greater than angle B
[or at the glass-water boundary, ray R₁ refracts away from the normal] \checkmark (2)

- (b)(i) (use of $\sin \theta_c = \frac{1}{n}$ gives) $\sin 48.8 = \frac{1}{n} \quad \checkmark$
 $n = 1.3 \quad \checkmark$ (1.33)

- (ii) use of $\frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2} \quad \checkmark$

$$\frac{\sin 48.8}{\sin 42.9} = \frac{c_{\text{water}}}{c_{\text{glass}}} \quad \checkmark$$

$$\frac{c_{\text{water}}}{c_{\text{glass}}} = 1.1 \quad \checkmark \quad (1.11) \quad (5)$$

Question 6

Q6 Jan 2005

- (a) $c_g (= \frac{c_a}{n}) = \frac{3 \times 10^8}{1.5} \quad \checkmark$
 $= 2.0 \times 10^8 \text{ m s}^{-1} \quad \checkmark$ (2)

- (b)(i) $\sin \theta_1 (= n \sin \theta_2) = 1.5 \times \sin 15 \quad \checkmark$
 $\theta_1 = 23^\circ \quad \checkmark$ (22.8°)

- (ii) use of $\frac{n_2}{n_1} = \frac{\sin \theta_1}{\sin \theta_2} \quad \checkmark$ (or equivalent)

$$n_2 = \frac{1.5 \times \sin 60}{(\sin 90)} \quad \checkmark$$

$$= 1.3 \quad \checkmark$$

(5)

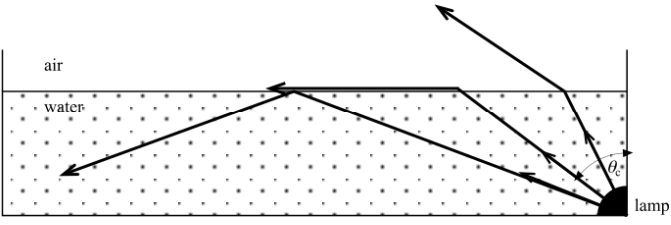
- (c) total internal reflection at A \checkmark
correct refraction out of glass at r.h. surface \checkmark (same angles as l.h. side) (2)
(9)

Quality of Written Communication marks: Q3 (a) (i) and Q5 (b) (iii) $\checkmark \checkmark$ (2)
(2)

| Question 4 | Q4 Jun 2005 | |
|------------|--|----------|
| (a) | diagram to show: total internal reflection on side face ✓ ray emerging at base bent away from normal ✓ with \approx correct angles ✓ | 3 |
| (b) | $n = \frac{1}{\sin \theta_c} \quad \checkmark$ $= \frac{1}{\sin 45} \quad \text{with calculation } \checkmark (= 1.41)$ | 2 |
| (c) | $\sin \theta_i = n \sin \theta_r \quad \checkmark$ $\sin \theta_i = 1.41 \times \sin 40 \quad \checkmark$ $\theta_i = 65^\circ \quad \checkmark$ | 3 |

| Question 5 | Q5 Jan 2006 | |
|------------|---|-----------|
| (a) (i) | $\left(\text{use of } n = \frac{\sin \theta_1}{\sin \theta_2} \text{ gives} \right) 1.45 = \frac{\sin \theta_1}{\sin 15.5^\circ} \quad \checkmark$ $\theta_1 = 22.8^\circ \quad \checkmark$ | 7 |
| (ii) | $n = \frac{1}{\sin \theta_c} \quad \checkmark$ $n = \left(\frac{1}{\sin 38.7^\circ} \right) = 1.6(0) \quad \checkmark$ | |
| (iii) | $\text{use of } {}_1n_2 = \frac{\sin \theta_1}{\sin \theta_2} \text{ and } {}_1n_2 = \frac{n_2}{n_1} \quad \checkmark$ <p>[or $n_1 \sin \theta_i = n_2 \sin \theta_r$]</p> $1.45 \sin \theta_3 = 1.60 \sin 51.3 \quad \checkmark$ $\theta_3 = 59.4^\circ \quad \checkmark$ (allow C.E. for value of n from (ii)) | |
| (b) | block 1 ✓(requires some explanation) reference to $\frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2} \quad \checkmark$ [or statement such as light refracts/bends towards normal as it enters a denser/higher refractive index material, or block 1 has lower refractive index] | 2 |
| (c) | reflection at boundary with $i = r \quad \checkmark$ refraction (at bottom surface) bending away from normal ✓ | 2 |
| | Total | 11 |

| Question 3 | | |
|--------------|--|-----------|
| (a) | $n = \left(\frac{\sin \theta_1}{\sin \theta_2} \right) = \frac{\sin 15.0^\circ}{\sin 10.0^\circ} \checkmark (= 1.49)$ | 1 |
| (b) | TIR on hypotenuse and refraction at top surface \checkmark 55°, 10° and 15° all marked correctly \checkmark | 2 |
| (c) | <p>(i) use of ${}_1n_2 = \frac{\sin \theta_1}{\sin \theta_2}$ and ${}_1n_2 = \frac{n_2}{n_1}$ Q3 Jun 2006 [or $n_1 \sin \theta_1 = n_2 \sin \theta_2$] \checkmark $1.49 \sin 55^\circ = 1.37 \sin \theta_2 \checkmark$ $\theta_2 = 63^\circ \checkmark$</p> <p>(ii) (use of $n = \frac{c_1}{c_2}$) gives $1.37 = \frac{3.0 \times 10^8}{c_2} \checkmark$ $c_2 = 2.2 \times 10^8 \text{ m s}^{-1} \checkmark$ ($2.19 \times 10^8 \text{ ms}^{-1}$)</p> <p>(iii) refraction at boundary between prisms, refracted away from normal \checkmark emerging ray (r.h. vertical face) refracting away from normal \checkmark</p> | 7 |
| Total | | 10 |

| Question 6 | | |
|--------------|---|----------|
| (a) | <p>(i) use of $n_w = \text{speed of light in air} / \text{speed of light in water} \checkmark$ $c_w (= 3.00 \times 10^8 / 1.33) = 2.26 \times 10^8 \text{ ms}^{-1} \checkmark$</p> <p>(ii) use of $n = 1 / \sin \theta_c$ $\theta_c (= \sin^{-1}(1 / 1.33)) = 48.8^\circ \checkmark$ Q6 Jan 2007</p> | 3 |
| (b) |  <p style="text-align: right;">mark for each ray $\checkmark\checkmark\checkmark$</p> | 3 |
| (c) | <p>the critical angle (for water-oil boundary) is larger \checkmark there is a smaller difference between the refractive index of the oil and water than there is between the air and water \checkmark</p> | 2 |
| Total | | 8 |

| | | |
|-------------------|--|----------|
| Question 4 | | |
| (a) | (i) the angle of incidence at the more dense - less dense boundary ✓ producing an angle of refraction of 90° ✓ (or definitions in terms of minimum or maximum angles of incidence for TIR or refraction) | 4 |
| | (ii) use of $\sin \theta_c = 1/n$ ✓ $\theta (= \sin^{-1} 1/1.54) = 40.5^\circ$ ✓ | |
| (b) | ray P showing TIR ✓ ray Q showing refraction at 90° ✓ ray R showing correct refraction ✓ | 3 |

Q4 Jan 2008

| | | |
|--------------|--|-----------|
| (c) | (i) ray would leave the core bending away from the normal increase in critical angle reference to light speed increase | 6 |
| | (ii) to protect the core or to prevent leakage of light or to prevent cross-talk ✓ | |
| | (iii) ${}_1n_2 = \sin \theta_1 / \sin \theta_2 = n_2 / n_1$ ✓ $\theta_c = \sin^{-1} (1.46/1.54)$ ✓ $\theta_c = 71.5^\circ$ ✓ | |
| Total | | 13 |

any two points ✓✓

| | | |
|-------------------|--|-----------|
| Question 5 | | |
| (a) | (i) $n_{\text{glass}} (= \sin \theta_{\text{air}} / \sin \theta_{\text{glass}}) = \sin 45^\circ / \sin 29^\circ$ ✓ $n_{\text{glass}} = 1.46$ ✓ | 5 |
| | (ii) use of ${}_{\text{glass}}n_{\text{gel}} = n_{\text{gel}} / n_{\text{glass}} = \sin \theta_{\text{glass}} / \sin \theta_{\text{gel}}$ or $\sin \theta_c = \frac{n_2}{n_1}$ or $\frac{n_{\text{gel}}}{n_{\text{glass}}}$ ✓ $n_{\text{gel}} = 1.46 \times \sin 74^\circ / \sin 90^\circ$ ✓ $n_{\text{gel}} = 1.40$ ✓ | |
| (b) | TIR from the bottom surface ✓ with 74° marked ✓ refracting away from the normal from the side of the prism ✓ emergent ray (horizontal) with angles marked ✓ | 4 |
| (c) | $v (= cn) = 3.00 \times 10^8 / 1.59 (= 1.89 \times 10^8 \text{ m/s})$ ✓ $t (= s/v) = 5.00 / 1.89 \times 10^8 = 2.65 \times 10^{-8} \text{ s}$ ✓ [2 → 4 sig fig] | 2 |
| Total | | 11 |

Q5 Jun 2008