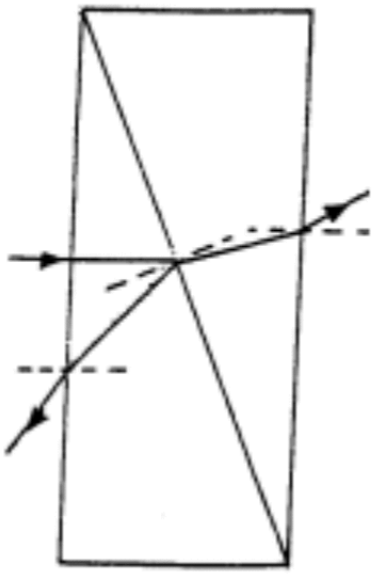
Mark Scheme Refraction Past Paper Questions
Jan 2002 to Jan 2009

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) ✓	
	(ii)	ray P shown in the air to right of vertical ✓ refracted away from the normal in the correct direction ✓ correct partial reflection shown ✓	**4**
(b)	(i)	**critical angle** for water-air boundary = 49.0° or angle of (incidence of) Q is θ_c ✓ the angle of incidence (of R) exceeds the critical angle ✓	
	(ii)	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)	**6**
		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 ✓

(*4*)

(b)(i) 20^o ✓

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

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

$\theta_2 = 17(.4)^o$ ✓ (*4*)

Q4 Jan 2002

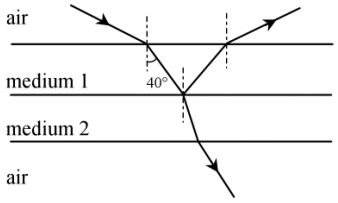
(c) (sin $\theta_c = 1/n$ gives) $\sin\theta_c = 1/1.60$ ✓

$\theta_c = 38.7^o$ ✓ (*2*)

(*10*)

Q3 Jun 2002

3(a)



(i) incident angle > 40° ✓
angle of refraction into medium 2 < 40° ✓
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) $\left(\text{use of } {}_1n_2 = \frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2} \text{ gives}\right)$ $\frac{1.65}{1.35} = \frac{\sin 40}{\sin\theta_2}$ ✓ ✓
$\theta = 31.7^\circ$ ✓ (*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*)

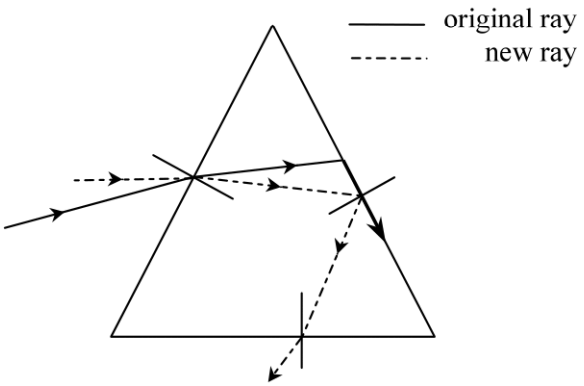
Q7 Jan 2003

7
(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) $n = \frac{\sin\theta_1}{\sin\theta_2}$ ✓
$(\theta_2 = 90 - 75.2 = 14.8^\circ)$
θ_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) $c_{glass}\left(= \frac{3.00 \times 10^8}{1.45}\right) = 2.07 \times 10^8 \text{ m s}^{-1}$ ✓

Q5 Jun 2003

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

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

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

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

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

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

[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 ✓
refraction at bottom surface with angle in air greater than that in the liquid (29.2°) ✓ (*2*)

(*7*)

3

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

(ii) speed of light decreases on entry into glass <u>and</u> increases on leaving ✓ (*4*)

(b)(i) (use of $\sin\theta_c = \frac{1}{n}$ gives) $\sin\theta_c = \frac{1}{1.57}$ ✓

Q3 Jan 2004

$\theta_c = 39.6^\circ$ ✓

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

$\sin \theta_c = \frac{1}{1.07}$ ✓

$\theta_c = 69.4^o$ ✓

(iii) to protect the core surface
[or to prevent cross-over] ✓ (6)

(10)

4

Q4 Jun 2004

(a)(i) (angle) F ✓

(ii) angle D is greater than angle B
[or at the glass-water boundary, ray R_1 refracts away from the normal] ✓ (2)

(b)(i) (use of $\sin \theta_c = \frac{1}{n}$ gives) $\sin 48.8 = \frac{1}{n}$ ✓

$n = 1.3$ ✓ (1.33)

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

$\frac{\sin 48.8}{\sin 42.9} = \frac{c_{water}}{c_{glass}}$ ✓

$\frac{c_{water}}{c_{glass}} = 1.1$ ✓ (1.11) (5)

Question 6

Q6 Jan 2005

(a) $c_g \left(= \frac{c_a}{n}\right) = \frac{3 \times 10^8}{1.5}$ ✓

$= 2.0 \times 10^8 \text{ m s}^{-1}$ ✓ (2)

(b)(i) $\sin \theta_1 \left(= n \sin \theta_2\right) = 1.5 \times \sin 15$ ✓

$\theta_1 = 23°$ ✓ (22.8°)

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

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

$= 1.3$ ✓ (5)

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

(9)

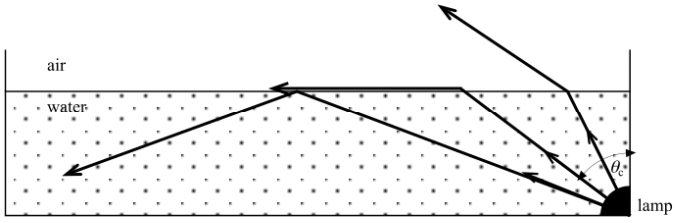
Quality of Written Communication marks: Q3 (a) (i) and Q5 (b) (iii) ✓✓ (2)

(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 ≈ correct angles ✓	**3**
(b)	$n = \frac{1}{\sin\theta_c}$ ✓ $= \frac{1}{\sin 45}$ with calculation ✓ (= 1.41)	**2**
(c)	$\sin\theta_i = n \sin\theta_r$ ✓ $\sin\theta_i = 1.41 \times \sin 40$ ✓ $\theta_i = 65°$ ✓	**3**

Question 5		Q5 Jan 2006	
(a)	(i)	(use of $n = \frac{\sin\theta_1}{\sin\theta_2}$ gives) $1.45 = \frac{\sin\theta_1}{\sin 15.5^\circ}$ ✓ $\theta_1 = 22.8^\circ$ ✓	**7**
	(ii)	$n = \frac{1}{\sin\theta_c}$ ✓ $n = \left(\frac{1}{\sin 38.7^\circ}\right) = 1.6(0)$ ✓	
	(iii)	use of ${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2}$ and ${}_1n_2 = \frac{n_2}{n_1}$ ✓ [or $n_1 \sin\theta_1 = n_2 \sin\theta_1$] $1.45 \sin\theta_3 = 1.60 \sin 51.3$ ✓ $\theta_3 = 59.4^\circ$ ✓ (allow C.E. for value of n from (ii))	
(b)		block 1 ✓(requires some explanation) reference to $\frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$ ✓ [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 ✓ refraction (at bottom surface) bending away from normal ✓	**2**
		Total	**11**

Question 3		
(a)	$n = \left(\frac{\sin\theta_1}{\sin\theta_2}\right) = \frac{\sin 15.0^\circ}{\sin 10.0^\circ}$ ✓ (= 1.49)	**1**
(b)	TIR on hypotenuse **and** refraction at top surface ✓ 55º, 10º and 15º all marked correctly ✓	**2**
(c) (i)	use of $_1n_2 = \frac{\sin\theta_1}{\sin\theta_2}$ and $_1n_2 = \frac{n_2}{n_1}$ **Q3 Jun 2006** [or $n_1 \sin\theta_1 = n_2 \sin\theta_2$] ✓ $1.49 \sin 55^\circ = 1.37 \sin\theta_2$ ✓ $\theta_2 = 63^\circ$ ✓	**7**
(ii)	(use of $n = \frac{c_1}{c_2}$) gives $1.37 = \frac{3.0\times10^8}{c_2}$ ✓ $c_2 = 2.2 \times 10^8$ m s^{-1} ✓ (2.19×10^8 m s^{-1})	
(iii)	refraction at boundary between prisms, refracted away from normal ✓ emerging ray (r.h. vertical face) refracting away from normal ✓	
	Total	**10**

Question 6		
(a) (i)	use of n_w = speed of light in air/speed of light in water ✓ c_w (= $3.00 \times 10^8/1.33$) = 2.26×10^8 ms^{-1} ✓	**3**
(ii)	use of $n = 1 / \sin\theta_c$ θ_c (= $\sin^{-1}(1 / 1.33)$) = 48.8º ✓ **Q6 Jan 2007**	
(b)	 mark for each ray ✓✓✓	**3**
(c)	the critical angle (for water-oil boundary) is larger ✓ there is a smaller difference between the refractive index of the oil and water than there is between the air and water ✓	**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 θ_c = 1/n ✓ θ (= sin^{-1} 1/1.54) = 40.5° ✓ **Q4 Jan 2008**	
(b)		ray P showing TIR ✓ ray Q showing refraction at 90° ✓ ray R showing correct refraction ✓	3

(c)	(i)	ray would leave the core bending away from the normal increase in critical angle reference to light speed increase **any two points** ✓✓	
	(ii)	to protect the core or to prevent leakage of light or to prevent cross-talk ✓	6
	(iii)	$_1n_2$ = sin θ_1/sin θ_2 = n_2/n_1 ✓ θ_c = sin^{-1} (1.46/1.54) ✓ θ_c = 71.5° ✓	
		Total	13

Question 5			
(a)	(i)	n_{glass} (= sin θ_{air}/sin θ_{glass}) = sin 45°/sin 29° ✓ n_{glass} = 1.46 ✓ **Q5 Jun 2008**	
	(ii)	use of $_{glass}n_{gel}$ = n_{gel}/n_{glass} = sin θ_{glass}/sin θ_{gel} or sin θ_c = $\frac{n_2}{n_1}$ or $\frac{n_{gel}}{n_{glass}}$ ✓ n_{gel} = 1.46 × sin 74°/sin 90° ✓ n_{gel} = 1.40 ✓	5
(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 (= c/n) = 3.00 × 10^8/1.59 (= 1.89 × 10^8 m/s) ✓ t (= s/v) = 5.00/1.89 × 10^8 = 2.65 × 10^{-8} s ✓ [2 → 4 sig fig]	2
		Total	11