Question	Answer	Marks	AO Element	Notes	Guidance
1	n = 1 / sin C in any form **OR** (n =) 1 / sin C (1) {(n=) 1 / sin 45 **OR** (n=) 1 / 0.707} **AND** (n=) 1.41 (1)	2			
2(a)(i)	*(n)* = sin *i* / sin *r* in any form, words or symbols **OR** sin 53° / sin 30° (1) 1.6 (1)	2			
2(a)(ii)	path emerging into air along correct path (by eye) **AND** labelled R	1			
2(b)	path labelled V with two correct refractions **AND** below path of red light in glass	1			
3(a)	3.0×10^8 m / s	1			
3(b)	n = c_a / c_w in any form **OR** (c_w =) c_a / n (1) (c_w=) 3.0×10^8 / 1.3 (1) (c_w=) 2.3×10^8 m / s (1)	3		accept ecf from (a)	
4	ratio / division of two identical quantities / speeds / sine functions / (pure) numbers (1)	1			

Question	Answer	Marks	AO Element	Notes	Guidance
5(a)	light (from water / from coin / to air / to eye) bends / changes direction / is refracted (1) refracts / bends away from normal **OR** angle of incidence is smaller than angle of refraction (1)	2			
5(b)	refraction	1			
5(c)	rays do not meet at image / only appear to come from image / do not originate from image / cannot be seen on a screen owtte	1			
6(a)	40°	1			
6(b)	*n* = 1.3 **OR** seen in calculation (1) *sin i ÷ sin r = n* in any form **OR** sin 40 ÷ *sin r = n* **OR** *sin i ÷ sin r = 1 ÷ n* (1) (*sin r* = 1.3 × sin 40°) (*r* =) 57° (1)	3			

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7	$n = \dfrac{\sin i}{\sin r}$ in any form **OR** $n_1 \sin \theta_1 = n_2 \sin \theta_2$ **OR** $1.3 = \dfrac{\sin 67°}{\sin r}$ **OR** $(r =) \sin^{-1}(\sin 67° / 1.3)$ **OR** $\sin^{-1}(0.71)$ (1) 45° (1)	2			
8	n = speed in air / speed in ice **OR** $n = V_{AIR} / V_{ICE}$ **OR** $(V_{ICE}) = V_{AIR} / n$ **OR** $3.0 \times 10^8 / 1.3$ (1) 2.3×10^8 m/s (1)	2			
9(a)	total internal reflection (at side AC) **OR** internal reflection **AND** no refraction (1) angle of incidence greater than critical angle / 42° (and refractive index of glass greater than that of air) (1)	2			

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9(b)	light <u>refracts</u> (at Y) (1) <u>angle of incidence</u> less than critical angle / 42° (1) (some) light reflects (1)	3			
10	*refracted wavelengths:* in glass, at least 3 wavefronts parallel to each other **AND** continuous with incident wavefronts, unless drawn to right of incident wavefronts (1) smaller wavelength than incident wavefronts **AND** equally spaced (1) at smaller angle with surface than incident wavefronts and rotated clockwise compared to incident wavefronts (1)	3			
11	*reflected wavefronts:* in air, at least 3 wavefronts parallel to each other (1) same spacing as incident wavefronts (1) reflecting at same angle with surface as incident wavefronts (1)	3			

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12(a)	one more reflection on top wall of fibre, between X and end of fibre **AND** no reflections on lower wall of fibre **AND** ray reaches end of fibre	1			
12(b)	*sin c* = 1 / *n* in any form (1) (c = sin^{-1}(1 / 1.46) =) 43° (1)	2			
12(c)	any **two** from: to carry (telephone) signals / communications for medical diagnosis / imaging specified artistic (display) specified lighting	2			
13(a)	dispersion	1			
13(b)	point A: red point B: violet	1			
13(c)	different speeds / refractive indices / refractions (for different colours / wavelengths)	1			
14	(n =) $c \div v$ **OR** $(3.0 \times 10^8) \div (1.9 \times 10^8)$ (1) 1.6 (1)	2			

Question	Answer	Marks	AO Element	Notes	Guidance
15	n = speed in air / speed in water **OR** speed in water = 3.0×10^8 / 1.33 (1) 2.3×10^8 m / s (1)	2			
16(a)	n = sin i / sin r **OR** sin r = sin i / n **OR** sin r = sin 35 / 1.50 (1) r = 22° (1)	2			
16(b)	refraction at XY drawn with r < i (1) refraction at XZ drawn with r > i (1)	2			
16(c)	blue ray drawn below red ray in prism and drawn with r < i (1) ray to right of prism diverging downwards from red ray (1)	2			
17	C - 37°	1			
18(a)	(n =) speed in air / speed in liquid (n = 3×10^8 / 2.0×10^8) = 1.5	2			
18(b)	n = sin i / sin r in any form (r = $\sin^{-1}$ (sin 40 / 1.5) =) 25°	2			

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					[Total: 57]