Refraction, Reflection and Polarisation - Mark Scheme

Q1.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>*</td><td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
Indicative content

• Ultrasound is reflected from boundaries/baby
• (This reflection is caused by) change in density
• Time taken between pulse being sent and received measured
• Speed of ultrasound is known
• Speed = distance/time can be used (to calculate the distance to boundary)
• Clear indication that this calculation includes ½ time or ½ distance

(Candidates can potentially achieve 1 linkage mark if they have scored both IC1 and IC2. They can potentially achieve 1 linkage mark if they have scored 3 of IC3-6)
</td><td>(6)</td></tr>
</table>

Q2.

Question Number	Answer	Mark
	C is the correct answer A is not the correct answer as the intensity does not vary as the filter is rotated B is not the correct answer as the intensity does not vary as the filter is rotated D is not the correct answer as one filter will allow some oscillations to pass	**(1)**

Q3.

Question Number	Answer		Mark
a	Vibrations/oscillations in one plane which includes the direction of wave travel **Or** Vibrations/oscillations in one direction perpendicular to the direction of wave travel	(1) (1) (1) (1)	**(2)**
b	The refracted ray lacks the planes of oscillation in the reflected light. **Or** the refracted ray has a plane of polarisation perpendicular to the plane of polarisation of the reflected light So, the refracted ray must also be partially plane polarised (MP2 conditional on awarding MP1)	(1) (1)	**(2)**
ci	See $n_a\sin\theta_a = n_g\sin\theta_g$ **Or** $n_a\sin\theta_B = n_g\sin r$ $n_a\sin(\theta_B) = n_g\sin(90 - \theta_B)$ **Or** $n_a\sin(\theta_B) = n_g\cos(\theta_B)$ **Or** $\sin r = \cos\theta_B$ $\sin(\theta_B)$ divided by $\cos(\theta_B)$ to give $\tan(\theta_B)$ leading to answer	(1) (1) (1)	**(3)**
cii	Substitution of values into $\tan(\theta_B) = \frac{n_g}{n_a}$ $\theta_B = 56°$ **Example of calculation** $\tan(\theta_B) = \frac{n_g}{n_a}$ $\theta_B = \tan^{-1}(1.50 / 1.00) = 56°$	(1) (1)	**(2)**
ciii	Refractive index (of glass) is greater for violet **Or** $\frac{n_g}{n_a}$ is greater for violet **Or** $\tan\theta_B$ / $\sin\theta_B$ / θ_B is greater for violet Clearly links one of the above to the student being incorrect.	 (1) (1)	**(2)**
	Total for question		**11**

Q4.

Question Number	Answer	Mark
a	There is a decrease in speed/velocity (1) Part of the wavefront meets the boundary before the rest (1) (Ignore references to density and refractive index) (Allow MP2 for correct addition to the diagram by eye for wavefronts both before and after the boundary)	(2)
bi	Use of $v = \sqrt{\frac{g\lambda}{2\pi}}$ to find speed in deep water (1) Use of $v = \sqrt{(gd)}$ to find speed in shallow water (1) Calculates ratio of speeds (1) Correctly equates ratio of speeds to ratio of sine of each angle (1) $r = 17°$ (1) <u>Example of calculation</u> $v = \sqrt{\frac{g\lambda}{2\pi}} = \sqrt{\frac{(9.81 \text{ms}^{-2} \times 15 \text{ m})}{2\pi}} = 4.8 \text{ ms}^{-1}$ (deep water) $v = \sqrt{(gd)} = \sqrt{(9.81 \text{ ms}^{-2} \times 0.50 \text{ m})} = 2.2 \text{ ms}^{-1}$ (shallow water) ratio of speeds = $(4.8 \text{ ms}^{-1}) / (2.2 \text{ ms}^{-1}) = 2.2$ $\sin r = \sin(40) / 2.2 = 0.29$ $r = 17°$	(5)
ii	Use of $f = 1/T$ and $v = f\lambda$ to find speed of wave (1) Use of $v = \sqrt{\frac{g\lambda}{2\pi}}$ to find same speed in deep water, confirming that deep water equation is the correct equation for this wave (1) Deep water equation only works if $d > 342 / 2$ so d must be > 171m (1) <u>Example of calculation</u> $f = 1 / 14.8 \text{ s} = 0.0676 \text{ Hz}$ $v = 0.0676 \text{ Hz} \times 342 \text{ m} = 23.1 \text{ ms}^{-1}$ $v = \sqrt{\frac{g\lambda}{2\pi}} = \sqrt{\frac{(9.81 \text{ms}^{-2} \times 342 \text{ m})}{2\pi}} = 23.1 \text{ ms}^{-1}$ (deep water)	(3)

Q5.

Question Number	Answer		Mark
a	For light travelling in a more (optically) dense substance and meeting a less (optically) dense substance **Or** for light travelling a material with higher RI and meeting one with a lower RI	(1)	
	Angle of incidence is greater than (or equal to) the critical angle	(1)	**2**
b	Wave slows down as it enters the glass	(1)	
	Part of the wave(front) meets the glass first, so wave direction changes	(1)	
	OR		
	Refractive index of glass is greater than that of air Or Density of glass is greater than that of air	(1)	
	So angle of incidence is greater than the angle of refraction (accept "bends towards the normal")	(1)	**2**
c	Use of sin $C = 1/n$ for glass-air boundary	(1)	
	Subtracts calculated critical angle from 90°	(1)	
	Use of $n_1\sin\theta_1 = n_2\sin\theta_2$ for glass-water boundary	(1)	
	$\theta = 59°$	(1)	**4**
	(For MP3, both 1.50 and 1.30 need to be seen in the calculation). Example of calculation Critical angle for glass-air boundary = $\sin^{-1}(1.00 / 1.50) = 41.8°$ Angle of incidence for glass-water boundary = 90° - 41.8° = 48.2° $1.50 \times \sin(48.2°) = 1.30 \times (\sin\theta)$ $\theta = 59.3°$		
	Total for question		**8**

Q6.

Question Number	Answer		Mark
a	(Pulse reflects at) a boundary between different materials/media/densities (allow "between steel and air" for "between different materials") (allow "speed of ultrasound in air is different to that of steel")	(1)	**(1)**
b	**Method 1** (Calculating distance to crack) Reads time difference of 24.5 - 25 μs from graph Use of speed = distance/time to calculate distance Uses half time or half distance in calculation Depth = 7.1 - 7.3 cm < 15cm, so reflection is from a crack **Or** Depth = 7.1 - 7.3 cm < 15cm, so cannot be from bottom of rail **OR Method 2** (Calculating time to bottom of rail and back) Use of speed = distance/time to calculate time Uses 30cm in calculation Reads time difference of 24.5 - 25 μs from graph Time = 52μs > 24.5 – 25 μs , so reflection is from a crack **Or** Time = 52μs > 24.5 – 25 μs , so cannot be from the bottom of rail **Example of calculation** Time between transmitting and receiving = 24.75μs So time taken to get to point of reflection = 12.375μs Distance = speed × time = 5800 m s^{-1} × (12.375 × 10^{-6}) = 0.072 m	(1) (1) (1) (1) (1) (1) (1) (1)	**(4)**
c	Most/all of the ultrasound is reflected by the first crack **Or** Pulse does not reach second crack **Or** None of the pulse is transmitted after the crack **Or** Ultrasound signal from deeper cracks is too weak to be detected	(1)	**(1)**
d	The idea that there is a time delay before reflected/received signals return The idea that the train will no longer be in the same position if it is moving too fast. **Or** the idea that the train will be in the same/similar position of it is moving slowly	(1) (1)	**(2)**
	Total for question		**8**