

Mark Scheme

Q1.

Question Number	Answer	Mark
	D is the correct answer as 45° is beyond the critical angle, so total internal reflection takes place A is not the correct answer as there will also be some reflection at this angle B is not the correct answer as there will also be some refraction at this angle C is not the correct answer as there will be no refraction at this angle.	(1)

Q2.

Question Number	Answer	Mark
	The only correct answer is C (All the light is reflected) A is not correct because none of the light will be refracted B is not correct because none of the light will be transmitted D is not correct because all the light will be reflected and none transmitted.	1

Q3.

Question Number	Answer	Mark
	B is the correct answer A is not correct because 1.33 should multiply the sin of the refracted angle in water C is not correct because the equation is inverted D is not correct because the equation is inverted and 1.33 should multiply the sin of the refracted angle in water	1

Q4.

Question Number	Answer	Mark
	C is the correct answer as light travels faster in L than in M A is not the correct answer as light travels faster in L than in M B is not the correct answer as light travels faster in L than in N D is not the correct answer as light travels faster in N than in M	(1)

Q5.

Question Number	Answer	Mark
	A is the correct answer B is not the correct answer as TIR can only take place when light is travelling from a more optically dense medium to a less optically dense medium. C is not the correct answer as TIR can only take place when light is travelling from a more optically dense medium to a less optically dense medium. D is not the correct answer as TIR can only take place when light is travelling from a more optically dense medium to a less optically dense medium.	(1)

Q6.

Question Number	Answer	Mark
	B is the correct answer as the light bends towards the normal when travelling from L to M (so $v_L > v_M$) but bends away from the normal when travelling from M to N, but there is not as much of a change of direction as there was from L to M. A is not the correct answer as light bends away from the normal travelling from M to N so v_N must be greater than v_M C is not the correct answer as light bends towards the normal travelling from L to M so v_L must be greater than v_M D is not the correct answer as light bends away from the normal travelling from M to N, so v_N must be greater than v_M	(1)

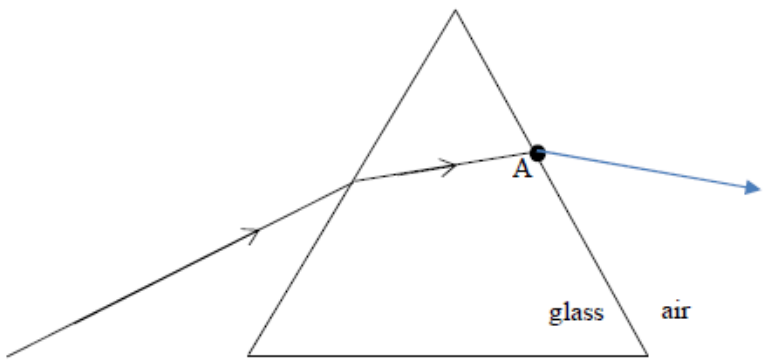
Q7.

Question Number	Answer	Mark
	A is the correct answer as, for total internal reflection to take place, the angle of incidence should be greater than the critical angle, when travelling from a substance with a higher refractive index towards a substance with a lower refractive index. B is not the correct answer as total internal reflection cannot take place if the light travels towards a boundary beyond which the refractive index increases. C is not the correct answer as total internal reflection cannot take place if the angle of incidence is less than the critical angle. D is not the correct answer as total internal reflection cannot take place if the angle of incidence is less than the critical angle.	(1)

Q8.

Question Number	Answer	Mark
	The only correct answer is A $\left(\theta > \sin^{-1} \left(\frac{1.40}{1.75} \right) \right)$ B is not correct because $\theta > \sin^{-1} \left(\frac{1.40}{1.75} \right)$ C is not correct because $\theta > \sin^{-1} \left(\frac{1.40}{1.75} \right)$ D is not correct because $\theta > \sin^{-1} \left(\frac{1.40}{1.75} \right)$	1

Q9.

Question Number	Answer	Mark
ai	Angle of incidence = 58° and angle of refraction = 40° (1) Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (1) Refractive index of glass = 1.3 (1) (Allow MP2 if angles of 32° and 50° are used) <u>Example of calculation</u> $n_1 \sin \theta_1 = n_2 \sin \theta_2$ $1.00 \times \sin 58^\circ = n_2 \times \sin 40^\circ$ $n_2 = 1.32$	3
aii	Ray drawn refracting away from the normal (1) (Normal line does not need to be drawn on diagram) 	1
b	Use of $n = c/v$ with $c = 3.00 \times 10^8 \text{ ms}^{-1}$ and $n = 1.63$ (1) Speed of light in glass = $1.8 \times 10^8 \text{ m s}^{-1}$ (1) <u>Example of calculation</u> $v = \frac{c}{n} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{1.63} = 1.84 \times 10^8 \text{ m s}^{-1}$	2
Total for question		6

Q10.

Question Number	Answer	Mark
a	Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ with both 1.33 and 1.52 seen (1) angle of refraction = 37° (1) <u>Example of calculation</u> $n_1 \sin \theta_1 = n_2 \sin \theta_2$ $1.33 \sin (43^\circ) = 1.52 \sin r$ $r = 36.6^\circ$	2
b	Use of $\sin C = 1/n$ (1) critical angle = 61° (1) OR Use of $\sin C = 1 / 1.14$ (if ratio calculated in (a)) (1) critical angle = 61° (1) (Allow an ecf of n_1 / n_2 ratio from (a)) <u>Example of calculation</u> $\sin C = 1/n$ $C = \sin^{-1} (1.33/1.52) = 61.0^\circ$	2
Total for question		4

Q11.

Question Number	Answer	Mark
(a)	Use of $n = \frac{c}{v}$ (1) $v = 2.26 \times 10^8 \text{ m s}^{-1}$ (1) <u>Example calculation</u> $v = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{1.33} = 2.256 \times 10^8 \text{ m s}^{-1}$	2

Question Number	Answer	Additional Guidance	Mark
(a)(i)	Use of $n = \frac{c}{v}$ with $c = 3 \times 10^8 \text{ m s}^{-1}$ (1) $v = 1.7 \times 10^8 \text{ m s}^{-1}$ (1)	<u>Example of calculation</u> $v = \frac{3 \times 10^8 \text{ m s}^{-1}}{1.75} = 1.71 \times 10^8 \text{ m s}^{-1}$	2
(a)(ii)	Angle of incidence = 34.9° and Angle of refraction = 26.0° (1) Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ with $n_2 = 1.75$ (1) Concentration = 3.0% (allow range 3.0 to 3.5) (1) Concentration is 3.0% which is closest to 3.2% so it is sample 2 Or Comparison of calculated concentration with values in the table and consistent conclusion (1)	If concentration is determined to be 3.2 then accept "it is sample 2" for MP4 <u>Example of calculation</u> $n_1 \times \sin 34.9^\circ = 1.75 \times \sin 26.0^\circ$ $n_1 = 1.341$ Concentration = 3.0% which is closest to 3.2% so it is sample 2	4
(b)	The ray shows the maximum angle of incidence Or The angle of incidence is almost 90° (1) So this is the maximum angle of refraction for the glycerol sample (1)		2
Total for question			8

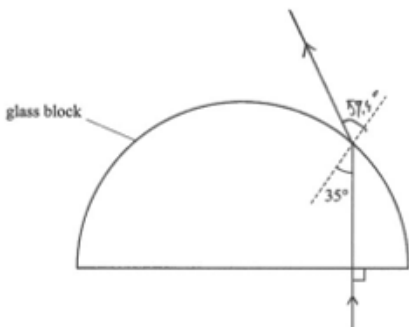
Q13.

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 <u>critical angle</u> (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 (1) Or Density of glass is greater than that of air 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) $\theta = 59^\circ$ (1) (For MP3, both 1.50 and 1.30 need to be seen in the calculation). <u>Example of calculation</u> Critical angle for glass-air boundary = $\sin^{-1}(1.00 / 1.50) = 41.8^\circ$ Angle of incidence for glass-water boundary = $90^\circ - 41.8^\circ = 48.2^\circ$ $1.50 \times \sin(48.2^\circ) = 1.30 \times (\sin \theta)$ $\theta = 59.3^\circ$	4
Total for question		8

Q14.

Question Number	Answer	Mark
a	Angle of incidence measured from diagram in range 54-56(°) (1) Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ with their measured angle of incidence (1) $\theta_2 = 30$-32(°) (1) Normal line drawn correctly at point of incidence (1) Ray refracted towards normal (1) <u>Example of calculation</u> Angle of incidence measured as 55° $n_1 \sin \theta_1 = n_2 \sin \theta_2$ so $1.00 \times \sin 55^\circ = 1.58 \times \sin \theta_2$ $\theta_2 = \sin^{-1} \left(\frac{1.00 \times \sin 55^\circ}{1.58} \right) = 31.2^\circ$	5
b	Use of $n = c/v$ with $c = 3.00 \times 10^8 \text{ m s}^{-1}$ (1) Use of $\sin C = 1/n$ (1) $C = 41^\circ$ (1) <u>Example of calculation</u> $n = \frac{c}{v} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{1.96 \times 10^8 \text{ m s}^{-1}} = 1.53$ $\sin^{-1}(C) = \frac{1}{1.53}$ so $C = 40.8^\circ$	3
Total for question		8

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	The incident ray is perpendicular to the surface of the glass block Or Ray is incident along the normal to the surface Or Angle of incidence = $0(^{\circ})$ (1)	Allow wavefronts parallel to surface of glass block	1
(b)(i)	Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (1) $\theta = 59^{\circ}$ (1)	<u>Example of calculation</u> $1.5 \sin 35^{\circ} = \sin \theta_2$ $\theta_2 = 59.35^{\circ}$	2
(b)(ii)	Ray refracts on correct side of normal and angle consistent with (b)(i) (1)	<u>Example of diagram</u> 	1
(c)	Use of $\sin C = \frac{1}{n}$ (1) Use of trigonometry to calculate distance from centre to ray (1) Adds radius of block to distance from centre (1) $x = 75 \text{ mm}$ (1)	<u>Example of calculation</u> $\sin C = \frac{1}{1.5} = 0.67$ distance from centre to ray $0.67 = \frac{\quad}{45 \text{ mm}}$ $0.67 \times 45 \text{ mm} = 30.3 \text{ mm}$ (if left as a fraction calculation gives 30.0 mm) $x = 45 + 30.3 = 75.3 \text{ mm}$	4
	Total for question		8

Question Number	Answer	Mark
a	Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (1) Use of $n = c/v$ with $c = 3.00 \times 10^8 \text{ (m s}^{-1}\text{)}$ (1) $v = 1.4 \times 10^8 \text{ (m s}^{-1}\text{)}$ so material is cubic zirconia (1) (For MP1, allow use of $n = \sin i / \sin r$) (All marks can be achieved if candidate calculates n for all of the gemstones and compares to value calculated in MP1) <u>Example of calculation</u> $n_1 \sin \theta_1 = n_2 \sin \theta_2$, $1.00 \sin (50^\circ) = n_2 \sin (21^\circ)$, $n_2 = 2.14$ $n = c/v$, so $v = (3.00 \times 10^8 \text{ m s}^{-1}) / 2.14 = 1.4 \times 10^8 \text{ m s}^{-1}$	3

bi	Use of $\sin C = 1/n$ where $n = c/v$ (1) Critical angle for diamond is 24° (1) $(40.5^\circ > 24^\circ)$ so diagram shows reflection at the boundary (1) Ray completed showing TIR in correct direction by eye (1) OR Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (1) $n_1 \sin \theta_1 = 1.57$ (1) $(\sin \theta_2 > 1)$ so diagram shows reflection at the boundary (1) Ray completed showing TIR in correct direction by eye (1) (Only allow MP3 if TIR is drawn on the diagram, not just stated) <u>Example of calculation</u> $\sin C = 1/n = (1.24 \times 10^8 \text{ ms}^{-1}) / (3.00 \times 10^8 \text{ ms}^{-1}) = 0.41$. $C = \sin^{-1} (0.41) = 24^\circ$	4
bii	Silicon carbide has a greater refractive index (than diamond) (1) Or silicon carbide has a smaller critical angle (than diamond) Or critical angle for silicon carbide is 23° Or critical angle is still less than the angle of incidence Or $\sin \theta_2$ is still > 1 So total internal reflection (TIR) would (still) take place (MP2 dependent on MP1) (1) (Calculation of n for silicon carbide not good enough for MP1)	2
Total for question		9

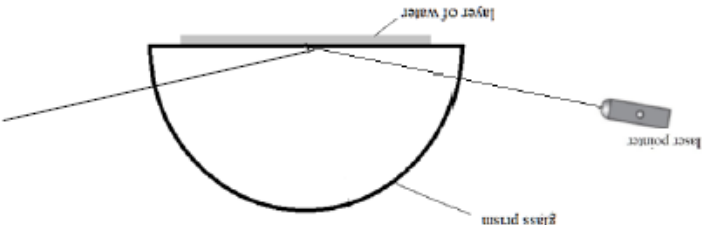
Q17.

Question Number	Answer	Mark
(a)	Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (1) r for violet light = 31.9° or r for red light = 32.3° (1) Use of trigonometry to calculate horizontal distances whilst in block (1) For violet, distance = 3.98 cm or for red, distance = 4.05 cm (1) Distance between points = 0.070 cm / 0.70 mm (1) (If working is only shown to 2 significant figures, the distances will come out to be the same. This can score MP1-4 only if all the working is clearly shown) (For MP1, allow use of $n = \sin i / \sin r$) (If candidate has the n values the wrong way round, MP1 can still be awarded if equation used correctly otherwise) <u>Example of calculation</u> $n_1 \sin \theta_1 = n_2 \sin \theta_2$. In air, $n_1 = 1.000$ and $\theta_1 = 54.00^\circ$ so, for violet light, $\sin r = \sin (54.00^\circ) / 1.532$, so $r = 31.88^\circ$ For red light, $\sin r = \sin (54.0^\circ) / 1.513$, so $r = 32.32^\circ$ For violet light, $\tan (31.88^\circ) = x / 6.400$ cm, so $x = 3.981$ cm For red light, $\tan (32.32^\circ) = x / 6.40$ cm, so $x = 4.049$ cm Distance between points = 4.049 cm – 3.981 cm = 0.068 cm	5
(b)	Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (1) Calculates $n \sin \theta$ as 0.99 for red Or 1.01 for violet (1) Red light refracts out of the glass as $n \sin \theta < 1$ (1) Violet light undergoes total internal reflection as $n \sin \theta > 1$ (1) (If candidate has the n values the wrong way round, MP1 can still be awarded if equation used correctly otherwise) OR Use of $\sin C = 1/n$ (1) Critical angle for violet = 40.7° Or critical angle for red = 41.4° (1) Red light refracts out of the glass as $C > i$ (1) Violet light undergoes total internal reflection as $C < i$ (1) <u>Example of calculation</u> $n \sin \theta$ for violet light = $1.532 \sin (41.00^\circ) = 1.005$. $n \sin \theta$ for red light = $1.513 \sin (41.00^\circ) = 0.993$.	4
Total for question		9

Q18.

Question Number	Answer	Mark
a	Idea that when waves rise from 900 m depth they speed up Or indication that speed at 700m is greater than at 900m (1) Curving is due to the change in speed being gradual Or not a sudden change in direction as there is no sudden change in speed. (1) Waves are refracted away from the normal (1) Angle of incidence reaches/exceeds the critical angle (at 700m) Or angle of refraction becomes 90° (at 700m) (1) (At 700 m, total internal) reflection takes place (allow TIR) (1)	5
b	Path in diagram B is a longer (distance) Or straight line path is a shorter (distance) (1) Sound waves travel faster on path in diagram B Or sound waves travel slower on straight line path Or sound waves travel faster at 700m than at 900m (1)	2
c	Any two from: (Change in) temperature in the sea (1) (Change in) pressure in the sea (1) (Change in) density/salinity of the sea (1)	2
Total for question		9

Q19.

Question Number	Answer	Mark
(a)	MAX 4 A wavefront is a line on which all points are in phase (1) The wavefronts are parallel to the boundary (between air and glass) Or The wavefronts are perpendicular to the normal Or Light is (travelling) along the normal Or Light is (travelling) perpendicular to the (surface of the) glass block (1) So all of the (points on the) wavefront enter the glass at the same time (1) The wave slows down (as it enters the glass block) (1) But the whole wavefront travels the same distance in the same time (so the ray does not change direction) (1)	4
(b)	Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (1) Substitution of $\theta_2 = 90^\circ$ (1) $c = 62^\circ$ (1) <u>Example of calculation</u> $1.51 \times \sin c = 1.33 \times \sin 90^\circ$ $c = 61.7^\circ$	3
(c)	Ray reflects off glass / water interface with no refracted ray (1) Angle of reflection = Angle of incidence (by eye) (1) Ray is undeviated at glass / air interface (1) <u>Example</u> 	3

(d)	(Some of) the light (travelling from the glass) is refracted/transmitted into the fingers/ridges/skin (1) Dark areas where fingers/ridges/skin is in contact with glass (1) (Some of) the light (travelling from the glass) is reflected from the air/valley (1) Light areas where air is in contact with glass. (1)	4
Total for question		14