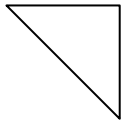
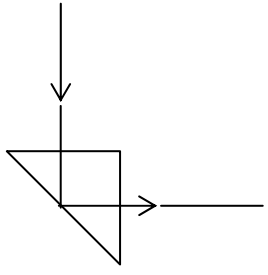
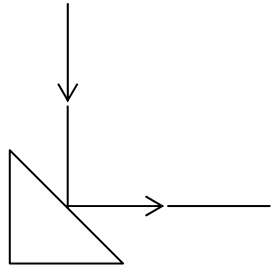
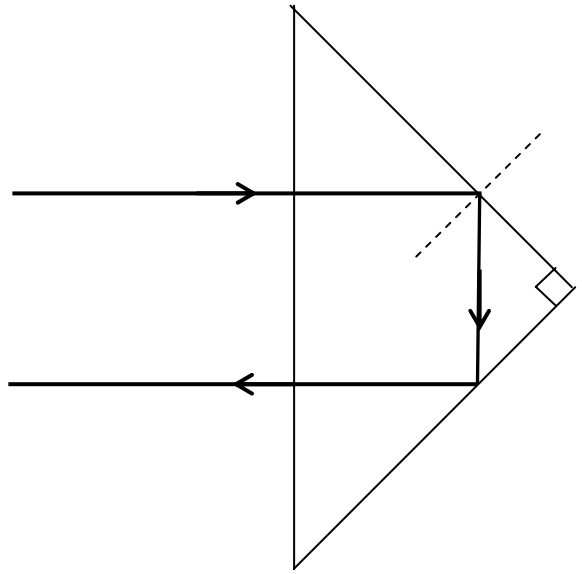
Question number	Answer	Notes	Marks
1 (a)	Idea of (correct) change of speed OR wavelength; (Refractive) index / (optical) density of glass > that of air (ORA);	Allow for 1 mark speed slower in glass OR wavelength shorter in glass (ORA) allow RI, n for refractive index	2
(b) (i)	sin c = 1/n ;	Allow rearrangements (n = 1/sin c) in words (incl critical angle)	1

Question number	Answer	Notes	Marks
1		(0.68199836)	
(ii)	(n=) 1/sin 43 OR sin 43° = 0.682 ; n = 1.47 (≈ 1.5) ;	(1.466279) Refractive index must be shown to > 2 sig fig Allow truncated values Reverse calculation can score 1 mark Reverse calculation with comparison can score both marks Bald answer can score 1 mark	1 2
(iii)	Any **three** of 1. larger RI means smaller c ; 2. TIR when **i>c;** 3. for diamond larg**er** range of angles for TIR ; 4. Some appropriate calculation, e.g. for diamond c = 25°; 5. 43° to 90° for TIR in opal;	**allow** c is smaller in diamond TIR happens at angles **smaller than** in opal/43° (1/2.4 = 0.417 → c=24.6°) Accept for 2 marks **25° to 90° for TIR in diamond; (MP2,4)** **Ignore** more of the rays going TIR (repeat of stem) diamond has a higher RI than opal	3
		Total	**8**

Question number		Answer	Notes	Marks
2 (a)		total internal reflection	Accept TIR	1
(b) (i)		prism drawn in correct orientation (by eye) 	Accept a freehand sketch of the triangular prism Size of prism unimportant, e.g. can fill the entire square, but horizontal and vertical edges must be drawn	1
(ii)		correct reflection of rays (by eye): 	Accept freehand sketch Accept correct external reflection e.g. reflection as shown below gets 1 mark for 1(b)(ii) despite the error in the 1(b)(i) response 	1

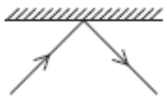
Question number	Answer	Notes	Marks
3 (a) (i)	total; internal; (reflection)	ACCEPT TIR for 2 marks 'total refraction' = 1, 'internal refraction' = 1 'total internal refraction' = 1 (list principle) 'reflection' alone = 0	1 1
(ii)	Any ONE of (Angle of) reflection ; θ > critical angle; 45º / 45 degrees / 45	ANSWER may be given on the DIAGRAM REJECT single letter 'r' REJECT θ = critical angle	1
(b)	Internal reflection at Y; Second internal reflection at lower right surface; Approximately correct reflections at both faces and emerging parallel (by eye); 	IGNORE any diagram arrows	3

Total 6 Marks

Question number	Answer	Notes	Marks
4 (a)	C (longitudinal waves)		1
(b)	FIVE marking areas – Reference to speed = distance travelled ÷ time taken; Measuring a time (of travel) for a known distance / measuring distance for a known time (of travel); Further appropriate detail for making a measurement; Idea of repeats / averaging / range of values; Realistic values for experiment to work suggested;	ACCEPT points made on a labelled diagram Need not be explicit, could be through description, e.g. 'and then divide the 100m by the time measured' examples – 'stand a known distance away from a wall and time how long it takes for an echo to come back' 'put two microphones on a bench connected to a CRO to measure the time it takes for a sound to go from one microphone to the other' stand at opposite sides of a room and time how long it takes for sound to go across' examples –stating suitable equipment and some indication of how to use it, e.g. 'have your partner facing away from you and start the timer when you make a sound – when they hear the sound they turn round and you stop the timer' Details of ALL relevant measurements NOT required, just one example e.g. – realistic – 'have your partner stand 100m away' 'stand 50m from a wall...time echo' 'place two microphones 1m apart...'	5

	ALTERNATIVE APPROACH – reference to speed = frequency x wavelength; indication of set up (e.g. signal generator and CRO); method to find wavelength (e.g. standing waves); method to find frequency (e.g. via timebase of CRO); additional relevant experimental detail;	e.g. – not realistic – 'have students stand 10m apart and time when they hear the sound...' 'use timers to measure the sound across a classroom' If no indication of values given – e.g. 'spread out on the school field' then this mark is NOT accessible	
(c) (i)	316 (±2) (m/s)		1
(ii)	Speed of sound decreases with height; Idea of linear relationship /constant rate;	IGNORE 'inversely proportional' IGNORE '*(directly) proportional' ACCEPT 'negative correlation	2
(iii)	Yes / Right (no mark) Aeroplane does not need to fly so fast (to make a sonic boom); Speed of sound lower (higher up) (ORA);	ACCEPT correct reference to graph, e.g. figures; IGNORE references to not being able to hear the boom from that high up IGNORE repetition from the stem – 'so it is easier for the plane to make a sonic boom' IGNORE all references to pressure/resistance/drag/friction/plane travels faster/	2

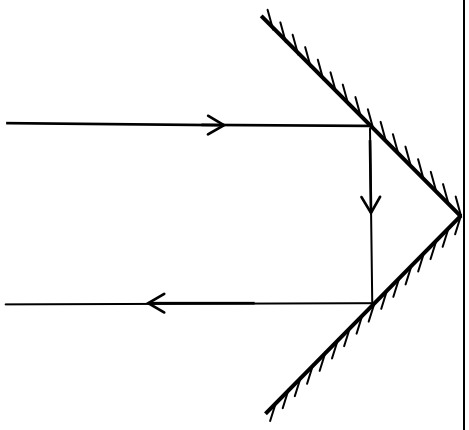
Total 11 Marks

Question number	Answer	Notes	Marks
5 (a)	 ☒ D		(1)
(b) (i)	normal drawn correctly;	judge by eye	(1)
(ii)	correct angle marked to their normal;	judge by eye	(1)
(iii)	correct angle chosen within ± 3°;	27°, no ECF from bi or bii	(1)
(iv)	$\frac{\sin i}{\sin r} = n$;	accept rearrangements	(1)
(v)	substitution; evaluation; e.g. $\frac{\sin 43}{\sin 27} = n$ 1.5	allow ECF from biii	(2)
(c) (i)	Total Internal Reflection;	accept TIR	(1)
(ii)	MP1. light reflects (inside (surface) of fibre); MP2. with angle i> critical angle; MP3. (because) light travels slower in glass;	condone light hits/bounces off the fibre wall	(3)

Total for Question 5 = 11 marks

Question number	Answer	Notes	Marks
6 (a)	D;		1
(b)	Any four of - MP1. mention of ray box/pins; MP2. Use of protractor; MP3. (vary *i* to) obtain a range of values; MP4. statement of equation; $n = \frac{\sin i}{\sin r}$ MP5. plot a graph of sin *i* against sin *r*; OR calculate/work out/ find *n*; MP6. find gradient of graph; OR calculate average of n; MP7. sensible experimental precaution; OR improvement to a basic method;	ignore reference to critical angle allow Snell's Law equation in words allow correct use of A and D from diagram including – • draw lines with a ruler, • use a thinner beam/slit, • use a monochromatic beam, e.g. red, • fix block firmly in position, • set any anomalous readings aside, • use a sharp pencil, • use a more precise protractor e.g. to ½º	4

Total 5 marks

Question number	Answer	Notes	Marks
7 (a)	Reflection at first surface correct; Ray emerges parallel; 	Judge diagram by eye	2
(b)	rearrangement and correct substitution; factor of 2 taken into account; value given to at least 2 significant figures; e.g. Time to reach moon = ½ x 2.6 = 1.3 (s) Distance = time x speed = 1.3 x 300 000 = 390 000 (km) OR Total distance = 2.6 x 300 000 = 780 000 So distance to moon = ½ x 780 000 = 390 000 (km)	working must be shown Reverse argument (starting with 400000 km) allow 2 max	3

Question number	Answer	Notes	Marks
7 (c) (i)	Any three of - MP1. idea that distance from Earth to Moon varies; MP2. idea that orbit of Moon is not (quite) circular; MP3. idea that change is cyclic / is regular / takes (about) a month; MP4. idea that Earth is not (quite) at centre of (moon) orbit; MP5. appropriate <u>use</u> of time data; MP6. appropriate calculation of a distance;	allow • further/nearer • orbit elliptical • orbit radius varies • sinusoidal • 26.5 / 27 days E.g. largest time difference = 2.70 – 2.47 = 0.23 s e.g. $\Delta s = ½ \times ct$ $= ½ \times 3 \times 10^8 \times 0.23$ = 34 500 km	3
(ii)	Any one of - MP1. (average) moon orbit radius becomes larger; MP2. moon moving away (from Earth); MP3. gravitational force (or gravity) becoming weaker;	Allow reverse argument	1

Total 9 marks