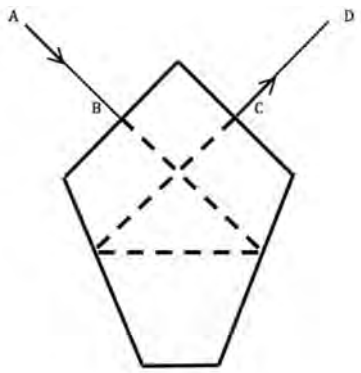
<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>1 (a)</td><td>3 or more correct lines = 2 marks
Any two correct lines = 1 mark

<table><tr><th>Notes about the total internal reflection of light</th><th>Right or wrong</th></tr><tr><td>the angle of incidence equals the angle of reflection</td><td>✓</td></tr><tr><td>light changes speed when it is internally reflected</td><td>×</td></tr><tr><td>every ray entering the semicircular glass block is reflected by total internal reflection</td><td>×</td></tr><tr><td>if i = 0 then the ray does not deviate</td><td>✓</td></tr><tr><td>the refractive index of glass is bigger than the refractive index of air</td><td>✓</td></tr></table></td><td></td><td>2</td></tr>
<tr><td>(b)</td><td>MP1 only two internal reflections attempted;
MP2 horizontal line from first TIR to second TIR;
MP3 ray does not deviate on exit;

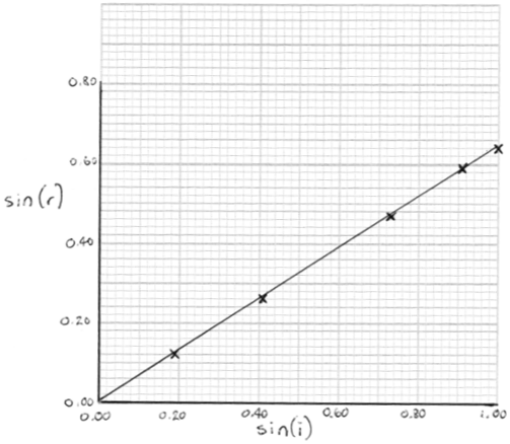
  </td><td>horizontal line by eye

ignore arrows</td><td>3</td></tr>
</table>

Question number	Answer	Notes	Marks
1 (c) (i)	Statement of sin c = 1/n; Substitution; Calculation; e.g. sin c = 1/n ……..worth 1 sin c = 1/1.5……..worth 2 (= 0.667) so c = 41.8º …….worth 3	 Value of c (or n) to at least 3 s.f. Allow reverse argument for max 2. Sin 42º = 0.669, giving n = 1.49 (“about 1.5”) Sin 42 x 1.5 =1.0036 ≈1 (sin 42 =1/1.5) Beware spurious maths that gives about 42 degrees	3
(ii)	Any two of the following ideas:- • RI = sin i /sin r • RI(n) is (only) a <u>number /ratio</u>; • a sine is a number /ratio;	allow $n = \text{speed}_1/\text{speed}_2$ n = 1/sin c proportion for ratio units cancel out	2
(d) (i)	Plot at 1.5, 42;	no tolerance	1
(ii)	Any one of - Fits the trend/pattern; (point is on) an extrapolation of line to;	 May be shown on graph OR e.g. “where the line would go”	1
(iii)	Any two of - MP1. Idea that a reduced scale gives full(er) use of grid; MP2. RI is always more than 1 (for incidence in air) MP3. angle c greater than ~20°;	 allow reduced scale fits the data ranges (of RI or c) ignore RI >0 allow angle c never zero	2

Total 14 marks

Question number	Answer	Notes	Marks
2 (a)	any three from: paper / pen / pencil; protractor; ruler / straight edge; light source (& power supply); (optical) pins;	 allow cork board ignore unqualified 'light' allow needles	3
(b) (i)	line drawn at P at 90° to the flat surface;	judge by eye	1
(ii)	41(°); 21(°);	tolerance +/- 3° no ECF	2
(iii)	change of medium / eq; change in speed / wavelength;	allow change of refractive index / (optical) density ignore changes direction reject second mark if contradiction seen	2

(c)	(i)	label on both axes; scale on both axes; plotting;;  	ignore orientation ignore any units linear scale using ≥50% of the grid tolerance is +/- 0.5 square -1 for each error sin *i* / sin *r*: 0.19 / 0.12; 0.41 / 0.26; 0.73 / 0.47; 0.91 / 0.59; 1.00 / 0.64	4
	(ii)	straight line of best fit (towards zero);	points should be evenly distributed about the line	1
	(iii)	n = sin i ÷ sin r	accept sine for sin	1
	(iv)	correct use of data from graph or table seen; value in range 1.54-1.60;	total marks = 16	2

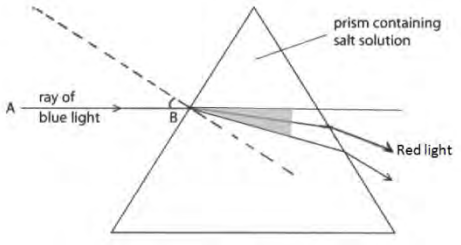
Question number	Answer	Notes	Marks
3 (a) (i)	Any two of - MP1. Idea that the reflection is (from a surface) inside the material; MP2. Idea that all of the light is reflected; MP3. Idea that reflection occurs inside the optically more dense medium; MP4. light incident at angle greater than critical angle	NB do not credit repeat of 'totally', 'internally' within Allow inside the higher refractive index medium	2
(ii)	Any two sensible uses – e. • optical fibres for communication; • in endoscopes; • optical fibres in decorative lamps/eq; • in safety reflector; • (Rectifying) prism in binoculars/telescope; • (Viewing) prism in camera; • (Reflecting) prism in periscope; • (Reflecting) prism in rangefinder;	allow only allow bald 'optical fibre' if no other O.F. mark given description of use e.g bicycle/car reflector, cat's eye	2
(b) (i)	B - OB		1
(ii)	sin c = 1/n	Allow rearrangements and abbreviations μ for n condone sin i for sin c	1
(iii)	Substitution and rearrangement in correct equation; Evaluation; e.g. n=1/sin 42° = 1/0.6691 n= 1.5	 1.49, 1.50 (1.4945)	2

Total 8 marks

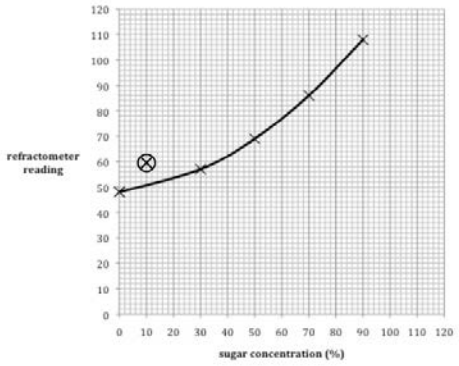
Question number	Answer	Notes	Marks
4 (a) (i)	D refraction;		1
(ii)	any 2 of: MP1. waves **slow down**; MP2. waves change direction/bend/angle; MP3. wavelength **decreases**;	allow 'light' for waves do not allow 'curved' allow wavefronts closer together	2
(b) (i)	line at 90° to the surface at point of contact;	judge by eye label not required	1
(ii)	angle between normal and incident ray clearly indicated;	allow ecf from normal line drawn in (b)(i) allow measured value in degrees	1

Total 5 marks

Question number	Answer	Notes	Marks
5 (a) (i)	change of direction of a wave (as it changes from 1 medium to another);	allow definition in terms of change of speed condone 'bending of light'	1
(ii)	MP1. right angle by eye; MP2. incident angle marked; MP3. incident angle value in range 31° to 34°;	allow normal labelled with right angle (90° or symbol) Give 2 marks (MP2 and MP3) for answer in range without a marked incident angle	3

iii	 MP1. $r_r > r_b$; MP2. $r_r < i$; MP3. less refraction than for blue light on emergence;	red line above blue line inside prism refraction at first surface (inside grey area) exit rays diverge downwards	3

iv	what happens inside the prism ONE mark from:- MP1. (blue light will) refract more (at the first surface); MP2. it will be nearer the normal; MP3. 'r' will be smaller; what happens on emergence:- ONE mark from:- MP4. it will bend even more; MP5. so larger deviation than previously;	allow for MP1 it will go slower;	2

Question number	Answer	Notes	Marks
5 b i	 **Sugar concentration (%)** / **Refractometer reading** 0 / 48 10 / 60 30 / 57 50 / 69 70 / 86 90 / 108 axes labelled with units; scales correct and linear to cover at least half the grid on one of the axes; points;; (-1 for each incorrect point to a maximum of 2) curve of best fit drawn;		5

(ii)	point 10, 60 circled; (10,)50;	 allow 49-52	1 1
(iii)	63 / ans from candidates graph;	 ans in range 62-66	1
(iv)	Any two from • pattern sentence / positive correlation / positive slope; • gradient changes/nonlinearity discussed; • not through the origin;	 as one increases the other increases allow • refractometer readings increase faster than % sugar concentration • attempted mathematical description e.g. exponential or similar	2

(Total for Question 5 = 19 marks)