PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 5: WAVES AND PARTICLE NATURE OF LIGHT

REFLECTION, REFRACTION AND LENSES

SCORE	PERCENTAGE
/630	%

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Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $n = \frac{c}{v}$ (1) • Use of $n_1 sin\theta_1 = n_2 sin\theta_2$ (1) • Uses $\sin C = \frac{1}{n}$ (1) • Comparison of $C = 50°$ with 30° and conclusion (1)	Example of Calculation $n_{\text{(air-water)}} = \frac{3.0 \times 10^8}{2.25 \times 10^8} = 1.33$ $\sin 40 = 1.33 \sin\theta_2 \quad \theta_2 = 29°$ At X: $\sin C = \frac{1}{1.33}$ $C = 49° > 29°$ so refracted	4

Q2.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• measure angle of incidence at edge (53°) **(1)** • use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **(1)** • value of angle in glass = 32° **(1)**	±1° tolerance Allow ecf for candidate's value Example of calculation: $1 \times \sin 53° = 1.5 \times \sin\theta_2$ $\theta_2 = 32°$	3
(ii)	• show refraction towards normal entering glass and how refraction away from normal exiting glass **(1)**		1

Q3.

Question Number	Answer	Mark
	D	1

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• use of $n = c/v$ (1) • use of $\sin C = 1/n$ (1) • $C = 48.8^{\circ}$ so TIR does not occur (1)	Example of calculation $n = (3.00 \times 10^8 \text{ m s}^{-1}) / (2.25 \times 10^8 \text{ m s}^{-1})$ $n = 1.33$ $\sin C = 1 / n = 1 / 1.33$ $C = 48.8^{\circ}$	**(3)**

Q5.

Question Number	Answer	Mark
(a)	Change in direction of wave (accept ray or any named wave) (do not accept bend) **(1)** (Due to) change in (optical) density / speed / medium **(1)**	**2**

Question Number	Answer	Mark
(b)	There is no change in direction for the light (passing between the water and the gel) **Or** There is no refraction (as the light passes between the water and the gel) (accept … within the beaker) **(1)** The light must have the same/similar wave speed in the water and gel **(1)** (accept same/similar density for water and gel)	**2**

Q6.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ using angle of incidence = 20° (1) • r(blue) = 31.3° **and** r(red) = 31.1° **Or** Calculates difference between r(blue) and r(red) = 0.2° (1) • Compares their answer to an uncertainty of protractor of 0.5° with conclusion consistent with their answer (1)	Example of Calculation sin$r$(blue) = 1.517sin20 = 0.519 r (blue)=$\sin^{-1}$(0.519) = 31.3° sin$r$(red) =1.509sin20 = 0.516 r (red)=$\sin^{-1}$(0.516) = 31.1° 31.3° - 31.1° = 0.2° 0.2° < 0.5° so protractor is unsuitable	3

(ii)	**Either** • Use of $sinC = \frac{1}{n}$ (1) • 41.5° (1) • Compares their answer to 35° and concludes that red light is not totally internally reflected **or** conclusion consistent with their answer (1) **Or** • Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ with 35° and n=1 (1) • 60° (1) • Compares their answer to 90° with conclusion that red light is refracted **or** conclusion consistent with their answer (1)	Example of Calculation $\sin C = \frac{1}{1.509} = 41.5°$ $C > 35°$ so red light is not totally internally reflected	3

Q7.

Question Number	Acceptable Answers	Additional Guidance	Mark
	C		1

Q8.

Question Number	Acceptable answers		Additional guidance	Mark
	• difference in speed for air to cornea much greater than difference in speed from water to cornea **Or** lower refractive index for water to cornea (= 1.03)	**(1)**	MP1: Seeing values of refractive index as 1.03 and 1.38 is not enough, a comparison is required.	3
	• so less refraction **Or** so power of eye/cornea reduced **Or** so focal length of eye/cornea increased	**(1)**		
	• if goggles worn the interface is with air and refraction is as normal **Or** if goggles worn the interface is with air and image focused on retina	**(1)**		

Q9.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $P = 1/f$ • $f = 8.47$ (mm)	**(1)** **(1)**	Example of calculation $f = 1 / 118$ D = 8.47 mm	2
(ii)	• Use of $1/v + 1/u = 1/f$ (allow u and v reversed, but not f) • $u = 14.8$ mm (ecf for f from 19(a)(i))	**(1)** **(1)**	Example of calculation 1/20 mm + $1/u$ = 1/8.5 mm $u = 14.8$ mm	2
(iii)	• (Freshwater has a lower refractive index than seawater, so) there will be greater refraction of light on entering the lens • This means that the power of the lens is greater in freshwater **Or** this means that the focal length is less in freshwater • This means that the shortest distance will be decreased	**(1)** **(1)** **(1)**		3
(iv)	• Use of $n = c/v$ • $v = 2.2 \times 10^8$ m s^{-1}	**(1)** **(1)**	Example of calculation $1.37 = 3.00 \times 10^8$ m s^{-1} / v $v = 2.2 \times 10^8$ m s^{-1}	2

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	**Either** • Use of $n = \frac{c}{v}$ (1) • Use of $v = f\lambda$ (with v in coating) (1) • Use of path difference $= \frac{\lambda}{2}$ with factor of 2 (1) • $d = 9.1 \times 10^{-8}$ m (1) **OR** • Use of $v = f\lambda$ (with c in air) • Use of $n = \frac{\lambda_{air}}{\lambda_{coating}}$ • Use of path difference $= \frac{\lambda}{2}$ with factor of 2 $d = 9.1 \times 10^{-8}$ m	Example of calculation: $v = \frac{3.00 \times 10^{8}\ \text{m s}^{-1}}{1.38} = 2.17 \times 10^{8}\ \text{m s}^{-1}$ $\lambda = \frac{2.17 \times 10^{8}\ \text{m s}^{-1}}{6.00 \times 10^{14}\ \text{Hz}} = 3.62 \times 10^{-7}\ \text{m}$ $d = \frac{\lambda}{4} = \frac{3.62 \times 10^{-7}\ \text{m}}{4} = 9.06 \times 10^{-8}\ \text{m}$	4

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Red and blue light do not interfere destructively, so remain in the reflected light **Or** If green light is cancelled/eliminated, then red and blue light will remain in the reflected light. (1)		1

Q11.

Question Number	Answer	Additional Guidance	Mark
	• use of $n_1 sin\theta_1 = n_2 sin\theta_2$ **and** $n = \frac{c}{v}$ (1) • $v = 2.3 \times 10^8$ m s^{-1} (1) • conclusion comparing their answer to 3.0×10^8 m s^{-1} (1)	Accept use of $n_1 sin\theta_1 = n_2 sin\theta_2$ to establish that $n(water) > 1$ with conclusion referring to $n = \frac{c}{v}$ Example of calculation $n(water) = \frac{\sin 35}{\sin 26} = 1.3$ $v(water) = \frac{3.0 \times 10^8 ms^{-1}}{1.3} =$ 2.3×10^8 m s^{-1}	3

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• use of $1/f = 1/u + 1/v$ (1) • $u = 4.8$ cm (1)	Example of calculation 1/1.6 cm = 1/u + 1/ 2.4 cm u = 4.8 cm	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• use of $n = c / v$ (1) • use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **Or** $n = \sin i / \sin r$ with correct angles (1) • $\theta = 11°$ (1)	Accept use of $v_2 \sin\theta_1 = v_1 \sin\theta_2$ for MP1 and MP2 but $v_1 \sin\theta_1 = v_2 \sin\theta_2$ scores neither Example of calculation $n = 3 \times 10^8$ m s^{-1} / 2.18×10^8 m s^{-1} = 1.376 $1 \times \sin 15° = 1.376 \times \sin\theta$ $\theta = 10.8°$	3

Q13.

Question Number	Acceptable Answers		Additional Guidance	Mark
(i)	• Appropriate line of best fit	(1)		1
(ii)	• Calculates a gradient using at least half the drawn line • η=1.37 to 1.47 • leading to a conclusion that glass is silica **Or** conclusion consistent with their value for η	(1) (1) (1)	Example of calculation $\frac{0.9-0.05}{0.58} = 1.47$ silica	3

Q14.

Question Number	Answers	Additional Guidance	Mark
	D	sin 61° / sin 42°	**(1)**

Q15.

Question Number	Answer		Mark
(a)	Credit any sensible limitation Examples include: • blunt pencil, • protractor divisions only to one degree, • protractor of limited radius • method requires rays to be marked and then drawn on Limited precision – linked to limitation	(1) (1)	2
(b)	Use of refractive index = ratio of speeds Speed = 2.0×10^8 m s^{-1} Example of calculation speed in plastic = 3.0×10^8 m $s^{-1} \div 1.52$ = 1.97×10^8 m s^{-1}	(1) (1)	2
(b)(ii)	Use of $\sin c = 1/\mu$, $\sin c = 1/n$ (or equivalent, but must allow full solution if used correctly without further equations) critical angle = 41° Example of calculation $\sin c = 1/1.52$ $c = 41°$	(1) (1)	2
*(c)	**(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)** The light strikes the sides at an angle greater than the critical angle It undergoes total internal reflection It is reflected again It strikes the other end at less than the critical angle **Or** It is transmitted at the final boundary **Or** the ray has zero angle of incidence at the first end and is transmitted undeviated	 (1) (1) (1) (1)	4
	Total for question		10

Q16.

Question Number	Answer		Mark
(a)	Measure angles of incidence and refraction (clear variants accepted or correct angles shown on a diagram)('*i*' and '*r*' accepted) Plots sin *i* vs sin *r* Correct gradient identified for their graph (assume sin *i* on *y* axis unless stated otherwise, assume statements using 'vs' or 'against' state *y* axis first) [If angle of reflection referred to instead of refraction, only allow 2nd mark] (Allow 3rd but not 2nd mark if *i* vs *r* and point from line used in $\mu = \sin i / \sin r$)	**(1)** **(1)** **(1)**	**3**
(b)(i)	angle of incidence (for light travelling from denser medium) has angle of refraction of 90° (may refer to leaving along surface/boundary)	**(1)** **(1)**	**2**
(b)(ii)	Use of $\mu = \sin i / \sin r$ (accept stating $\sin c = 1 / \mu$) $c = 49°$ (n.b. ue applies) <u>Example of calculation</u> $\sin c = 1 / \mu = 1 / 1.33$ $c = 49°$	**(1)** **(1)**	**2**
	Total for question		**5**

Q17.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Light is refracted as it passes into medium 2 • Angle of refraction may be calculated using $n_1\sin\theta_1 = n_2\sin\theta_2$ • Angle of refraction = 89.81° • Angle of <u>incidence</u> at layer 2-3 is greater than the critical angle • So <u>total internal reflection</u> occurs (at layer 2-3 interface) • So light/ rays appear to come from surface of road (so that observer sees mirage)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	MP2 see use of the equation MP5 accept totally internally reflected and TIR MP6 is not just for saying there is a mirage. <u>Example of Calculation</u> $\sin^{-1}\left(\frac{1.00032 \times \sin 89.59°}{1.00030}\right)$ $= 89.81°$	**6**

Q18.

Question Number	Acceptable Answers		Additional Guidance	Mark
(i)	• use of $n_1 \sin i_1 = n_2 \sin i_2$ • with angle of incidence in plastic = 28° • angle of deviation = angle of refraction – angle of incidence • angle of deviation = 16°	(1) (1) (1) (1)	Example of calculation $n_1 \sin i_1 = n_2 \sin i_2$ $1.47 \sin (90° - 62°) = 1.00 \sin i_2$ $i_2 = 43.6°$ angle of deviation = 44° − 28° = 16°	4
(ii)	• Going from the centre of the lens towards the edge the angle of incidence in the plastic increases • The angle of deviation increases • (So) all rays cross (the axis) at the principal focus	(1) (1) (1)	Accept focal point for principal focus	3

Q19.

Question Number	Answer	Mark
	B $v_1 < v_2$ $n_1 > n_2$	1
	Incorrect Answers: A – incorrect equality for speed C – incorrect equality for speed and refractive index D – incorrect equality for refractive index	

Q20.

Question Number	Answer	Mark
	A	1

Q21.

Question Number	Answer	Mark
(a)	change in direction / wavelength (of wave/ray/light) (1) (when entering a medium where) the wave has a different velocity **OR** (when entering a medium where) the density is different (1) the light travels at a lower speed in the air than in a vacuum (1)	3
(b)	identify angle of incidence = 64° (1) use of sin i / sin r = refractive index (1) r = 63.9° to at least 3 sf (1) calculation of difference = 0.12° (1) Example of calculation sin r = sin $i \div \mu$ = sin 64° ÷ 1.001 r = 63.88° difference = 0.12°	4
	Total for question	7

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of trigonometry to determine angle of ray to normal in liquid (1) • Use of n sin θ = constant (1) • n = 1.42 (1)	Example of calculation (10.2 – 4.0) ÷ 2 = 3.1 cm tan θ = 3.1 cm / 35 cm θ = 5.06° n = sin 7.2° / sin 5.06° n = 1.42	3

Q23.

Question Number	Answer	Mark
	B	1

Q24.

Question Number	Answer	Mark
	A	1

Q25.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $n = c / v$ **(1)** • $v = 2.1 \times 10^8$ m s^{-1} (allow ecf from (a)) **(1)**	Example of calculation $v = c/n$ $= 3.00 \times 10^8$ m s^{-1} / 1.42 $= 2.11 \times 10^8$ m s^{-1}	**2**

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $n = \frac{c}{v}$ (1) • Use of $n_1 sin\theta_1 = n_2 sin\theta_2$ (1) • Uses $\sin C = \frac{1}{n}$ (1) • Comparison of $C = 50°$ with 30° and conclusion (1)	Example of Calculation $n_{\text{(air-water)}} = \frac{3.0 \times 10^8}{2.25 \times 10^8} = 1.33$ $\sin 40 = 1.33 \sin\theta_2 \quad \theta_2 = 29°$ At X: $\sin C = \frac{1}{1.33}$ $C = 49° > 29°$ so refracted	4

Q2.

Question Number	Answers	Mark
	The only correct answer is B *A is incorrect because the relative refractive index for light travelling from glass to water is required* *C is incorrect because the relative refractive index for light travelling from glass to water is required* *D is incorrect because the relative refractive index for light travelling from glass to water is required*	**1**

Q3.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• measure angle of incidence at edge (53°) **(1)** • use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **(1)** • value of angle in glass = 32° **(1)**	±1° tolerance Allow ecf for candidate's value Example of calculation: $1 \times \sin 53° = 1.5 \times \sin\theta_2$ $\theta_2 = 32°$	**3**
(ii)	• show refraction towards normal entering glass and how refraction away from normal exiting glass **(1)**		**1**

Q4.

Question Number	Answer	Mark
	B $\frac{1}{\sin 35}$	**1**
	Incorrect Answers: A – incorrect arrangement of equation C – incorrect arrangement of equation D – incorrect arrangement of equation	

Q5.

Question Number	Answer	Mark
	D	1

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• use of $n = c/v$ (1) • use of $\sin C = 1/n$ (1) • $C = 48.8°$ so TIR does not occur (1)	Example of calculation $n = (3.00 \times 10^8 \text{ m s}^{-1}) / (2.25 \times 10^8 \text{ m s}^{-1})$ $n = 1.33$ $\sin C = 1 / n = 1 / 1.33$ $C = 48.8°$	(3)

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• the angle of incidence in an (optically) denser medium at which the angle of refraction (in the less dense medium) is 90° (1) **Or** • the greatest angle of incidence in an (optically) denser medium at which there is an emergent ray (into the less dense medium) **Or** • the greatest angle of incidence in an (optically) denser medium at which there is a refracted ray (in the less dense medium)	Other equivalent answers may be given Do not accept answers stating or implying that the critical angle is the smallest angle at which total internal reflection occur, e.g., 'The smallest angle at which t.i.r. takes place', but do not automatically exclude answers on the basis of mentioning internal reflection alone without the inclusion of 'total' 'The greatest angle before t.i.r. takes place' is not sufficient	1
(ii)	• Use of $\sin C = 1 / n$ (1) • $C = 41°$ (1)	Example of calculation $\sin C = 1/1.52$ $C = 41.1°$	2

Q8.

Question Number	Answer	Mark
(a)	Change in direction of wave (accept ray or any named wave) (do not accept bend) (1) (Due to) change in (optical) density / speed / medium (1)	2

Question Number	Answer	Mark
(b)	There is no change in direction for the light (passing between the water and the gel) **Or** There is no refraction (as the light passes between the water and the gel) (accept … within the beaker) (1) The light must have the same/similar wave speed in the water and gel (1) (accept same/similar density for water and gel)	2

Q9.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ using angle of incidence = 20° (1) • r(blue) = 31.3° **and** r(red) = 31.1° **Or** Calculates difference between r(blue) and r(red) = 0.2° (1) • Compares their answer to an uncertainty of protractor of 0.5° with conclusion consistent with their answer (1)	Example of Calculation sin$r$(blue) = 1.517sin20 = 0.519 r (blue)=$\sin^{-1}(0.519)$ = 31.3° sin$r$(red) =1.509sin20 = 0.516 r (red)=$\sin^{-1}(0.516)$ = 31.1° 31.3° - 31.1° = 0.2° 0.2° < 0.5° so protractor is unsuitable	3

(ii)	**Either** • Use of $sinC = \frac{1}{n}$ (1) • 41.5° (1) • Compares their answer to 35° and concludes that red light is not totally internally reflected **or** conclusion consistent with their answer (1) **Or** • Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ with 35° and n=1 (1) • 60° (1) • Compares their answer to 90° with conclusion that red light is refracted **or** conclusion consistent with their answer (1)	Example of Calculation $\sin C = \frac{1}{1.509} = 41.5°$ $C > 35°$ so red light is not totally internally reflected	3

Q10.

Question Number	Answer		Mark
(a)	Credit any sensible limitation Examples include: • blunt pencil, • protractor divisions only to one degree, • protractor of limited radius • method requires rays to be marked and then drawn on Limited precision – linked to limitation	(1) (1)	2
(b)	Use of refractive index = ratio of speeds Speed = 2.0×10^8 m s^{-1} Example of calculation speed in plastic = 3.0×10^8 m $s^{-1} \div 1.52$ = 1.97×10^8 m s^{-1}	(1) (1)	2
(b)(ii)	Use of $\sin c = 1/\mu$, $\sin c = 1/n$ (or equivalent, but must allow full solution if used correctly without further equations) critical angle = 41° Example of calculation $\sin c = 1/1.52$ $c = 41°$	(1) (1)	2
*(c)	**(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)** The light strikes the sides at an angle greater than the critical angle It undergoes total internal reflection It is reflected again It strikes the other end at less than the critical angle **Or** It is transmitted at the final boundary **Or** the ray has zero angle of incidence at the first end and is transmitted undeviated	 (1) (1) (1) (1)	4
	Total for question		10

Q11.

Question Number	Answer		Mark
(a)	Measure angles of incidence and refraction (clear variants accepted or correct angles shown on a diagram)('*i*' and '*r*' accepted) Plots sin *i* vs sin *r* Correct gradient identified for their graph (assume sin *i* on *y* axis unless stated otherwise, assume statements using 'vs' or 'against' state *y* axis first) [If angle of reflection referred to instead of refraction, only allow 2nd mark] (Allow 3rd but not 2nd mark if *i* vs *r* and point from line used in $\mu = \sin i / \sin r$)	**(1)** **(1)** **(1)**	**3**
(b)(i)	angle of incidence (for light travelling from denser medium) has angle of refraction of 90° (may refer to leaving along surface/boundary)	**(1)** **(1)**	**2**
(b)(ii)	Use of $\mu = \sin i / \sin r$ (accept stating $\sin c = 1 / \mu$) $c = 49°$ (n.b. ue applies) <u>Example of calculation</u> $\sin c = 1 / \mu = 1 / 1.33$ $c = 49°$	**(1)** **(1)**	**2**
	Total for question		**5**

Q12.

Question Number	Answer	Mark
	A	**1**

Q13.

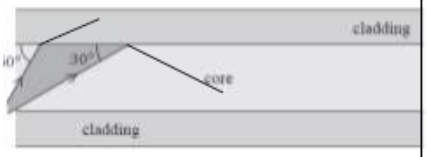
Question Number	Answer	Mark
(a)	change in direction / wavelength (of wave/ray/light) (1) (when entering a medium where) the wave has a different velocity **OR** (when entering a medium where) the density is different (1) the light travels at a lower speed in the air than in a vacuum (1)	3
(b)	identify angle of incidence = 64° (1) use of sin i / sin r = refractive index (1) r = 63.9° to at least 3 sf (1) calculation of difference = 0.12° (1) <u>Example of calculation</u> sin r = sin $i \div \mu$ = sin 64° ÷ 1.001 r = 63.88° difference = 0.12°	4
	Total for question	7

Q14.

Question Number	Answer	Mark
	A	1

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (1) • Angle in cladding $\theta = 90(°)$ (1) • Critical angle = 50.3(°) (1)	Accept alternative method using $\sin c = \frac{1}{n}$ **and** $n = \frac{c}{v}$ to give $n = \frac{v_{cladding}}{v_{core}}$ **Or** $n = \frac{n_{core}}{n_{cladding}}$ Use of $\sin c = \frac{1}{n}$ with n=1.2 or 1.56 gains 1 mark <u>Example of calculation</u> e.g. $1.56 \sin\theta_1 = 1.20 \sin\theta_2$ $1.56 \sin c = 1.20 (\sin 90°)$ $\sin c = \frac{1.20}{1.56}$ $c = 50.3(°)$	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Left hand side of beam refracts away from normal	(1)	Ignore any line continued beyond cladding Ignore any reflection	
	• Right hand side of beam totally internally reflected	(1)	Reflection correct by eye Do not award if any line shown in cladding	
	• State Student C is correct	(1)	**(MP3 dependent on MP1 and MP2)**  Arrows on rays not needed	3

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Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $n = \frac{c}{v}$ (1) • Use of $n_1 sin\theta_1 = n_2 sin\theta_2$ (1) • Uses $\sin C = \frac{1}{n}$ (1) • Comparison of $C = 50°$ with 30° and conclusion (1)	Example of Calculation $n_{\text{(air-water)}} = \frac{3.0 \times 10^8}{2.25 \times 10^8} = 1.33$ $\sin 40 = 1.33 \sin\theta_2 \quad \theta_2 = 29°$ At X: $\sin C = \frac{1}{1.33}$ $C = 49° > 29°$ so refracted	4

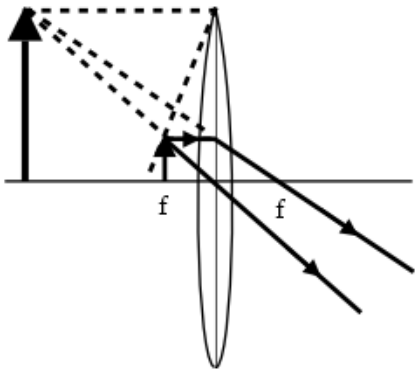
Q2.

Question Number	Answer	Mark
	D	1

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• use of $n = c/v$ (1) • use of $\sin C = 1/n$ (1) • $C = 48.8°$ so TIR does not occur (1)	Example of calculation $n = (3.00 \times 10^8 \text{ m s}^{-1}) / (2.25 \times 10^8 \text{ m s}^{-1})$ $n = 1.33$ $\sin C = 1 / n = 1 / 1.33$ $C = 48.8°$	**(3)**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	Two construction rays from: • ray from tip of object parallel to principal axis drawn then refracted through the focal point **(1)** • ray drawn from tip of object through centre of lens **(1)** • ray drawn from focal point through tip of object and then refracted parallel to the principal axis **(1)** **And** • rays extended back to locate tip of image on the same side as the object **(1)**	Example of diagram:  	**3**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $m = v/u$ **(1)** • Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ and substituting for v or u **(1)** • $u = 6.1$ cm **(1)**	Example of calculation: $\frac{v}{u} = -3.5 \quad \therefore v = -3.5u$ $\frac{1}{u}+\frac{1}{-3.5u}=\frac{1}{8.5} \quad \therefore \frac{3.5-1}{3.5u}=\frac{1}{8.5} \quad \therefore \frac{3.5u}{2.5}=8.5$ $u = \frac{8.5\times 2.5}{3.5} = 6.07 \text{ cm}$	**3**

Q5.

Question Number	Answer	Mark
(a)	Change in direction of wave (accept ray or any named wave) (do not accept bend) **(1)** (Due to) change in (optical) density / speed / medium **(1)**	2

Question Number	Answer	Mark
(b)	There is no change in direction for the light (passing between the water and the gel) **Or** There is no refraction (as the light passes between the water and the gel) (accept … within the beaker) **(1)** The light must have the same/similar wave speed in the water and gel **(1)** (accept same/similar density for water and gel)	2

Q6.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ using angle of incidence = 20° (1) • r(blue) = 31.3° **and** r(red) = 31.1° **Or** Calculates difference between r(blue) and r(red) = 0.2° (1) • Compares their answer to an uncertainty of protractor of 0.5° with conclusion consistent with their answer (1)	Example of Calculation sin$r$(blue) = 1.517sin20 = 0.519 r (blue)=sin^{-1}(0.519) = 31.3° sin$r$(red) =1.509sin20 = 0.516 r (red)=sin^{-1}(0.516) = 31.1° 31.3° - 31.1° = 0.2° 0.2° < 0.5° so protractor is unsuitable	3

(ii)	**Either** • Use of $sinC = \frac{1}{n}$ (1) • 41.5° (1) • Compares their answer to 35° and concludes that red light is not totally internally reflected or conclusion consistent with their answer (1) **Or** • Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ with 35° and n=1 (1) • 60° (1) • Compares their answer to 90° with conclusion that red light is refracted or conclusion consistent with their answer (1)	Example of Calculation $\sin C = \frac{1}{1.509} = 41.5°$ $C > 35°$ so red light is not totally internally reflected	3

Q7.

Question Number	Answer	Mark
	B – TIR as angle of incidence is greater than the critical angle	**1**
	Incorrect Answers: A – light is reflecting at an incorrect angle C – light is not refracted D – light is not refracted	

Q8.

Question Number	Acceptable answers		Additional guidance	Mark
	• Light strikes the edges of the long crystals at angles greater than the critical angle	(1)		**2**
	• It is repeatedly totally internally reflected along the crystal	(1)		

Q9.

Question Number	Answer		Mark
(a)	Credit any sensible limitation Examples include: • blunt pencil, • protractor divisions only to one degree, • protractor of limited radius • method requires rays to be marked and then drawn on Limited precision – linked to limitation	(1) (1)	2
(b)	Use of refractive index = ratio of speeds Speed = 2.0×10^8 m s^{-1} Example of calculation speed in plastic = 3.0×10^8 m $s^{-1} \div 1.52$ = 1.97×10^8 m s^{-1}	(1) (1)	2
(b)(ii)	Use of $\sin c = 1/\mu$, $\sin c = 1/n$ (or equivalent, but must allow full solution if used correctly without further equations) critical angle = 41° Example of calculation $\sin c = 1/1.52$ $c = 41°$	(1) (1)	2
*(c)	**(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)** The light strikes the sides at an angle greater than the critical angle It undergoes total internal reflection It is reflected again It strikes the other end at less than the critical angle **Or** It is transmitted at the final boundary **Or** the ray has zero angle of incidence at the first end and is transmitted undeviated	 (1) (1) (1) (1)	4
	Total for question		10

Q10.

Question Number	Answer		Mark
(a)	Measure angles of incidence and refraction (clear variants accepted or correct angles shown on a diagram)('*i*' and '*r*' accepted) Plots sin *i* vs sin *r* Correct gradient identified for their graph (assume sin *i* on *y* axis unless stated otherwise, assume statements using 'vs' or 'against' state *y* axis first) [If angle of reflection referred to instead of refraction, only allow 2nd mark] (Allow 3rd but not 2nd mark if *i* vs *r* and point from line used in $\mu = \sin i / \sin r$)	**(1)** **(1)** **(1)**	**3**
(b)(i)	angle of incidence (for light travelling from denser medium) has angle of refraction of 90° (may refer to leaving along surface/boundary)	**(1)** **(1)**	**2**
(b)(ii)	Use of $\mu = \sin i / \sin r$ (accept stating $\sin c = 1 / \mu$) $c = 49°$ (n.b. ue applies) <u>Example of calculation</u> $\sin c = 1 / \mu = 1 / 1.33$ $c = 49°$	**(1)** **(1)**	**2**
	Total for question		**5**

Q11.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Light is refracted as it passes into medium 2 • Angle of refraction may be calculated using $n_1\sin\theta_1 = n_2\sin\theta_2$ • Angle of refraction = 89.81° • Angle of <u>incidence</u> at layer 2-3 is greater than the critical angle • So <u>total internal reflection</u> occurs (at layer 2-3 interface) • So light/ rays appear to come from surface of road (so that observer sees mirage)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	MP2 see use of the equation MP5 accept totally internally reflected and TIR MP6 is not just for saying there is a mirage. <u>Example of Calculation</u> $\sin^{-1}\left(\frac{1.00032 \times \sin 89.59°}{1.00030}\right)$ $= 89.81°$	**6**

Q12.

Question Number	Answer	Mark
	B $v_1 < v_2$ $n_1 > n_2$	1
	Incorrect Answers: A – incorrect equality for speed C – incorrect equality for speed and refractive index D – incorrect equality for refractive index	

Q13.

Question Number	Answer	Mark
	A	**1**

Q14.

Question Number	Answer	Mark
(a)	change in direction / wavelength (of wave/ray/light) **(1)** (when entering a medium where) the wave has a different velocity **OR** (when entering a medium where) the density is different **(1)** the light travels at a lower speed in the air than in a vacuum **(1)**	**3**
(b)	identify angle of incidence = 64° **(1)** use of sin i / sin r = refractive index **(1)** r = 63.9° to at least 3 sf **(1)** calculation of difference = 0.12° **(1)** <u>Example of calculation</u> sin r = sin $i \div \mu$ = sin 64° ÷ 1.001 r = 63.88° difference = 0.12°	**4**
	Total for question	**7**

Q15.

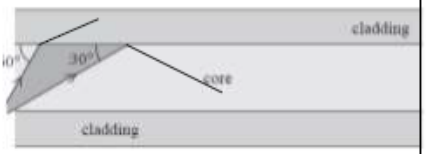
Question Number	Answer	Mark
	B	1

Q16.

Question Number	Answer	Mark
	A	1

Q17.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ • Angle in cladding $\theta = 90(°)$ • Critical angle = 50.3(°)	(1) (1) (1)	Accept alternative method using $\sin c = \frac{1}{n}$ **and** $n = \frac{c}{v}$ to give $n = \frac{v_{cladding}}{v_{core}}$ **Or** $n = \frac{n_{core}}{n_{cladding}}$ Use of $\sin c = \frac{1}{n}$ with n=1.2 or 1.56 gains 1 mark Example of calculation e.g. $1.56 \sin\theta_1 = 1.20 \sin\theta_2$ $1.56 \sin c = 1.20 (\sin 90°)$ $\sin c = \frac{1.20}{1.56}$ $c = 50.3(°)$	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Left hand side of beam refracts away from normal • Right hand side of beam totally internally reflected • State Student C is correct	(1) (1) (1)	Ignore any line continued beyond cladding Ignore any reflection Reflection correct by eye Do not award if any line shown in cladding **(MP3 dependent on MP1 and MP2)**  Arrows on rays not needed	3

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B because at angles less than or equal to the critical angle not all of the light is reflected internally such that angle of incidence is equal to the angle of reflection A is not correct because total internal reflection occurs at angles greater than the critical angle but at the critical angle the angle of refraction is 90 degrees, so the reflection is not total C is not correct because internal reflection is not total at angles less than the critical angle D is not correct because internal reflection is not total at angles less than the critical angle		1

Q19.

Question Number	Answers	Mark
	The only correct answer is D ***A** is incorrect because the angle of incidence must be greater than the critical angle* ***B** is incorrect because the angle of incidence must be greater than the critical angle **and** $n_1 < n_2$* ***C** is incorrect because the light must be incident upon the boundary in the medium with the larger refractive index*	1

Q20.

Question Number	Answer	Mark
(a)	(When light strikes a boundary with) angle of incidence greater than the critical angle **Or** When light within a denser medium strikes a boundary with a less dense medium **(1)** All of the light is reflected **Or** none of the light is transmitted **Or** none of the light is refracted **(1)**	2

Question Number	Answer		Mark
(b)(i)	Use of $\mu = \sin i / \sin r$ $x = 41(°)$ Example of calculation $\sin x = \sin 60° / 1.33$ $x = 40.6°$	(1) (1)	2
(b) (ii)	Use of $\mu = \sin i / \sin r$ with $i = 90°$ (accept stating $\sin c = 1 / \mu$) $c = 49(°)$ Example of calculation $\mu = \sin 90° / \sin c$ $\sin c = 1 / \mu = 1 / 1.33$ $c = 49°$	(1) (1)	2
(b) (iii)	Angle in gel < critical angle **Or** angle y < critical angle **Or** (If angle x = angle y, then this corresponds to an) angle in air of 60° Not total internal reflection so some light reaches screen **Or** Light will be refracted/transmitted so some light reaches screen	(1) (1)	2

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Object/star is at infinity, so (intermediate) image formed at focal length of objective lens (1) • (Final image at infinity), so object (intermediate image) must be at focal length of eyepiece lens (1) **Or** • Objective lens, $1/v + 1/u = 1/\underline{f}$, and $\underline{u}$ = infinity, so $v = f$ • Eyepiece lens, $1/v + 1/u = 1/f$, $\underline{v}$ = infinity so $u = f$	Appropriate references to parallel rays may be equivalent to object/image at infinity Example Objective: $1/v + 1/u = 1/f$, $u = \infty$, so $1/v + 1/\infty = 1/f$ $1/v + 0 = 1/f$ $v = f$ Eyepiece: $1/v + 1/u = 1/f$, $v = \infty$, so $1/\infty + 1/u = 1/f$ $0 + 1/u = 1/f$ $u = f$ Note: If both lenses are considered, $1/v + 1/u = 1/f$ does not have to be quoted twice	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• The rays cross over after the objective lens **Or** (1) • The objective lens inverts the image **Or** • The image formed by the eyepiece lens is on the same side as its object, so remains the same way up		1

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	• increases the power (of the eye) **Or** to decrease the image distance **Or** to shorten the focal length (of the eye and lens) **Or** to the eye it makes the rays appear to come from an object further away (1)	If a candidate states that the image is formed at the focal point or that the retina is at the focal point do not award this mark	1

Q3.

Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is **B** because m is the SI unit for length. A is not correct because C is not a base unit C is not correct because g is not a base unit D is not correct because °C is not a base unit	1

Q4.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ **(1)** • Use of $P=\frac{1}{f}$ **(1)** • P = 46 D / Dioptre / dioptre **(1)**	Accept MP2 if you see $\frac{1}{25}$ or $\frac{1}{2.4}$ for $\frac{1}{f}$ Example of Calculation $\frac{1}{0.25}+\frac{1}{0.024}=46$ D	3

Q5.

Question Number	Answer	Additional Guidance	Mark
	• Use of $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ **and** $P=\frac{1}{f}$ • Use of $P=P_1+P_2$ • (−) 0.6 D • Diverging	MP4 dependent on MP3 Example of calculation Power of eye $P=\frac{1}{1.5\text{ (m)}}+\frac{1}{0.024\text{(m)}}=42.3$ D P of spectacles = 41.7 (D) – 42.3 (D) = -0.6 D diverging	4

Q6.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Two straight lines drawn extrapolated from diverging rays meeting at a single point on the principal axis (1) • focal length = (-) 2.3 to 2.4 cm (1)	Accept dotted or solid lines	2

Q7.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Focus image of distant/far object on to a screen (1) • Measure distance from lens to screen (1) **Or** • Use <u>parallel</u> rays of light (1) • Measure distance from lens to the point where the rays converge (1)	MP2 dependent on MP1	2
(ii)	• Greater <u>refraction</u> (1) • To converge (parallel) rays at a point closer to the lens (1)		2
(iii)	• Photograph 2 has a greater magnification (1) • so v is greater (1) • since u is constant (1) • So f is greater (1) • Hence photograph 2 taken with lens of focal length 200 mm (1)	MP5 dependent on MP2 and MP4	5

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• difference in speed for air to cornea much greater than difference in speed from water to cornea **Or** lower refractive index for water to cornea (= 1.03) **(1)** • so less refraction **Or** so power of eye/cornea reduced **Or** so focal length of eye/cornea increased **(1)** • if goggles worn the interface is with air and refraction is as normal **Or** if goggles worn the interface is with air and image focused on retina **(1)**	MP1: Seeing values of refractive index as 1.03 and 1.38 is not enough, a comparison is required.	3

Q9.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Only a real image will be produced on a screen **(1)** • The object cannot be closer than *f* for a real image **(1)** • Because light diverges after passing through the lens **(1)** **OR** • If object closer than *f* rays still diverge after passing though lens **(1)** • So a virtual image is formed **(1)** • which cannot be seen on a screen. **(1)**		3

Q10.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • $f = 8.0 \times 10^{-2}$ m (1)	Example of calculation $\frac{1}{f} = \frac{1}{0.09\ \text{m}} + \frac{1}{0.75\ \text{m}}$ $f = 8.00 \times 10^{-2}$m	2

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ (1) • … with consistent units for u and f (1) • Use of displacement = $v - f$ (1) • Displacement of lens = 0.07 mm away from sensor (1)	Example of calculation $\frac{1}{25 \times 10^{-2}\ \text{m}} + \frac{1}{v} = \frac{1}{4.25 \times 10^{-3}\ \text{m}}$ $\therefore \frac{1}{v} = (235.3 - 4)\ \text{m}^{-1}$ $\therefore v = \frac{1}{231.3\ \text{m}^{-1}} = 4.32 \times 10^{-3}\ \text{m}$ Displacement of lens = (4.32 – 4.25) mm = 0.0735 mm	4

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	• Lens displacement is so minimal that v doesn't change much **Or** $u >> v$ so Δv doesn't change much **Or** $u >> f$ so displacement doesn't change much **Or** $u >> v$ so v approx. equal to f **Or** most object distances can be considered to be at infinity so will focus at about f (1)		1

Q13.

Question Number	Answer	Mark
	The onlv correct answer is C because 10 cm is more than the focal length from a converging lens A diverging lenses do not form real images from real objects B diverging lenses do not form real images from real objects D an object at less than the focal length from a converging lens will form a virtual image	1

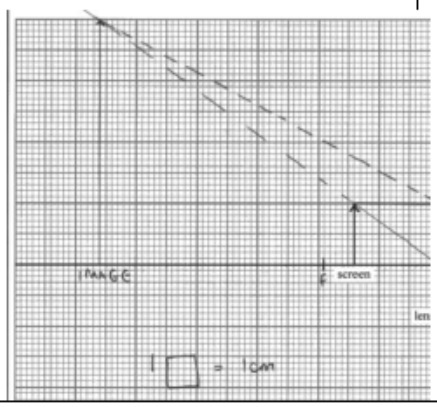
Q14.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $P = 1/f$ • $f = 8.47$ (mm)	(1) (1)	Example of calculation $f = 1 / 118$ D = 8.47 mm	2
(ii)	• Use of $1/v + 1/u = 1/f$ (allow u and v reversed, but not f) • $u = 14.8$ mm (ecf for f from 19(a)(i))	(1) (1)	Example of calculation 1/20 mm + $1/u$ = 1/8.5 mm u = 14.8 mm	2
(iii)	• (Freshwater has a lower refractive index than seawater, so) there will be greater refraction of light on entering the lens • This means that the power of the lens is greater in freshwater **Or** this means that the focal length is less in freshwater • This means that the shortest distance will be decreased	(1) (1) (1)		3
(iv)	• Use of $n = c/v$ • $v = 2.2 \times 10^8$ m s^{-1}	(1) (1)	Example of calculation $1.37 = 3.00 \times 10^8$ m s^{-1} / v $v = 2.2 \times 10^8$ m s^{-1}	2

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
	A		1

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	• Two rays correctly drawn including extrapolation (1) • Completes diagram with image at 10.6 cm (range 9.0 cm to 12.0 cm) (1) • Magnification = 3.8 (3.5 to 4.0) (1) • Conclusion consistent with values for distance and *M* (1)	Acceptable rays: • from arrowhead on object through the optical centre of the lens • from arrowhead on object parallel to the axis up to the lens and then through the principal focus on the other side • from the principal focus on the same side and through the arrowhead on the object to the lens and then parallel to the axis Example of calculation *M* = image size / object size (accept use of distances) = 8.0 cm / 2.0 cm = 4.0 	4

Q17.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• use of $1/f = 1/u + 1/v$ (1) • $u = 4.8$ cm (1)	Example of calculation 1/1.6 cm = 1/*u* + 1/ 2.4 cm *u* = 4.8 cm	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• use of $n = c / v$ (1) • use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ Or $n = \sin i / \sin r$ with correct angles (1) • $\theta = 11°$ (1)	Accept use of $v_2 \sin\theta_1 = v_1 \sin\theta_2$ for MP1 and MP2 but $v_1 \sin\theta_1 = v_2 \sin\theta_2$ scores neither Example of calculation $n = 3 \times 10^8$ m s^{-1} / 2.18×10^8 m s^{-1} = 1.376 $1 \times \sin 15° = 1.376 \times \sin\theta$ $\theta = 10.8°$	3

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of lens equation $1/f = 1/v + 1/u$ (1) • Use of magnification = v/u (1) • Magnification = 15 (1)	Example of calculation 1/17.9 mm = 1/v + 1/16.7 mm v = (-)249 mm magnification = 249 mm / 16.7 mm = 14.9	3

Q19.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• use of $n_1 \sin i_1 = n_2 \sin i_2$ (1) • with angle of incidence in plastic = 28° (1) • angle of deviation = angle of refraction – angle of incidence (1) • angle of deviation = 16° (1)	Example of calculation $n_1 \sin i_1 = n_2 \sin i_2$ $1.47 \sin(90° - 62°) = 1.00 \sin i_2$ $i_2 = 43.6°$ angle of deviation = 44° − 28° = 16°	4
(ii)	• Going from the centre of the lens towards the edge the angle of incidence in the plastic increases (1) • The angle of deviation increases (1) • (So) all rays cross (the axis) at the principal focus (1)	Accept focal point for principal focus	3

Q20.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Use of $m = \frac{image\ height}{object\ height}$ • Use of $m = \frac{v}{u}$	(1)	Example of Calculation $m = \frac{3.5\times10^{-3}\ m}{2.0\times10^{-4}\ m} = 17.5$	
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$	(1)	$v = 17.5 \times 5.0 \times 10^{-2} m = 0.875$ (m) $\frac{1}{f} = \frac{1}{5.0\times10^{-2}\ m} + \frac{1}{0.875\ m}$	
	• Use of $P = \frac{1}{f}$	(1)	$f = 0.047$ m	
	• 21 D	(1)	$P = \frac{1}{0.047\ m} = 21.1$ D	5

Q21.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	**Either** • Rays from (a point) on the moon are <u>parallel</u> • So the rays converge to the principal focus **Or** so the image is formed at the principal focus **Or** • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ with $u = \infty$ or very large • $f = v$	(1) (1) (1) (1)	Description of focal length as: the distance between the lens and point at which parallel rays will converge (after passing through lens), scores 2 Accept focal point for principal focus **(MP2 dependent on MP1)** **(MP2 dependent on MP1)**	2

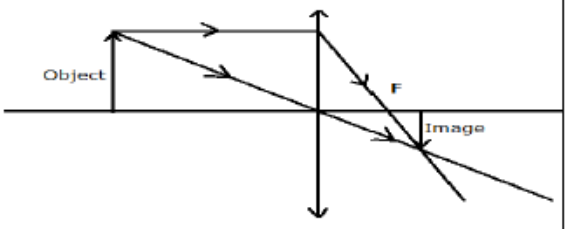
Question Number	Acceptable answers		Additional guidance	Mark
(ii)	Real Diminished Inverted	(2)	One/Two properties scores 1 mark Three properties score 2 marks Accept smaller Accept upside down	2

Q22.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	A ray diagram including: • ray from top of object through centre of lens to retina (1) • ray parallel to axis on one side of lens and through focal point on other side (1) • distance to near point = 6.0 cm (1)	Correct calculation scores MP3 only	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• use of $M = v/u$ (1) • M = 0.33 (2/3 sf) ecf u from (i) (1)	<u>Example of calculation</u> M = 2 cm / 6 cm = 0.33	**(2)**

Q23.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of a correct ray (1) • use of second correct ray (1) • indicates image formed where rays cross (1) • image drawn is real, inverted and diminished (1)	<u>Correct rays are:</u> Ray through the principal focus and parallel to the principal axis Ray parallel to principal axis then through the principal focus Ray through the optical centre of the lens <u>Example of diagram:</u> 	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• use of $1/f = 1/v + 1/u$ (1) for u estimate 4 – 10 mm • use of $P = 1/f$ (1) • P = (120 D to 230 D) (1)	Example of calculation: Assuming the thickness of 8 mm: $1/f = 1/0.008 + 1/0.045$ $P = 1/f$ P = 147 D Full credit for any thicknesses in range 4 – 10 mm	**(3)**

Q24.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• increasing the current through the coil increases the heating effect (1) • this causes the resistance of the coil to increase (due to the collisions between conduction electrons and lattice ions) (1) • so for a given p.d. this would result in the current decreasing (1) • this would increase the focal length of the lens, hence the need to limit the current (1)	MP4 conditional mark, dependent on MP3 being awarded	**(4)**

Q25.

Question Number	Answers	Mark
	The only correct answer is C ***A*** *is incorrect because the focal length of the lens increases* ***B*** *is incorrect because the focal length of the lens increases* ***D*** *is incorrect because lens power is the reciprocal of the focal length*	**1**

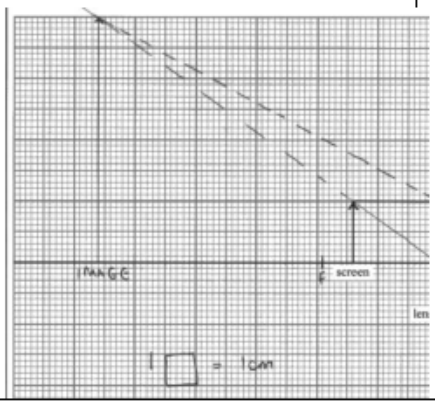
Mark Scheme

Q1.

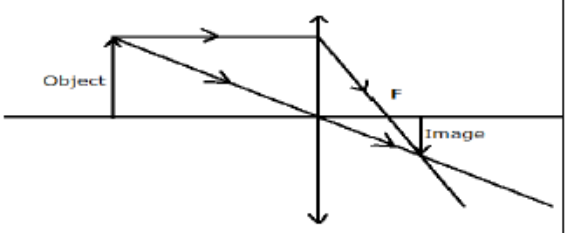
Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Object/star is at infinity, so (intermediate) image formed at focal length of objective lens (1) • (Final image at infinity), so object (intermediate image) must be at focal length of eyepiece lens (1) **Or** • Objective lens, $1/v + 1/u = 1/f$, and u = infinity, so $v = f$ • Eyepiece lens, $1/v + 1/u = 1/f$, v = infinity so $u = f$	Appropriate references to parallel rays may be equivalent to object/image at infinity Example Objective: $1/v + 1/u = 1/f$, $u = \infty$, so $1/v + 1/\infty = 1/f$ $1/v + 0 = 1/f$ $v = f$ Eyepiece: $1/v + 1/u = 1/f$, $v = \infty$, so $1/\infty + 1/u = 1/f$ $0 + 1/u = 1/f$ $u = f$ Note: If both lenses are considered, $1/v + 1/u = 1/f$ does not have to be quoted twice	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• The rays cross over after the objective lens **Or** (1) • The objective lens inverts the image **Or** • The image formed by the eyepiece lens is on the same side as its object, so remains the same way up		1

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	• Two rays correctly drawn including extrapolation (1) • Completes diagram with image at 10.6 cm (range 9.0 cm to 12.0 cm) (1) • Magnification = 3.8 (3.5 to 4.0) (1) • Conclusion consistent with values for distance and *M* (1)	Acceptable rays: • from arrowhead on object through the optical centre of the lens • from arrowhead on object parallel to the axis up to the lens and then through the principal focus on the other side • from the principal focus on the same side and through the arrowhead on the object to the lens and then parallel to the axis Example of calculation *M* = image size / object size (accept use of distances) = 8.0 cm / 2.0 cm = 4.0 	4

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of a correct ray (1) • use of second correct ray (1) • indicates image formed where rays cross (1) • image drawn is real, inverted and diminished (1)	Correct rays are: Ray through the principal focus and parallel to the principal axis Ray parallel to principal axis then through the principal focus Ray through the optical centre of the lens Example of diagram: 	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• use of $1/f = 1/v + 1/u$ (1) for u estimate 4 – 10 mm • use of $P = 1/f$ (1) • P = (120 D to 230 D) (1)	<u>Example of calculation:</u> Assuming the thickness of 8 mm: $1/f = 1/0.008 + 1/0.045$ $P = 1/f$ P = 147 D Full credit for any thicknesses in range 4 – 10 mm	**(3)**

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • Use of $P = P_1 + P_2 = 5\text{D}$ therefore use one lens with power of 2 (D) and one with power of 3 (D) (1)	Example of Calculation $v = 0.5 \times 0.6\text{ m} = 0.3\text{ m}$ $\frac{1}{f} = \frac{1}{0.6\text{ m}} + \frac{1}{0.3\text{ m}}$ $f = 0.2\text{ m}$ $P = 1/0.2\text{ m} = 5\text{D}$	4

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ (1) • Use of $P=\frac{1}{f}$ (1) • P = 46 D / Dioptre / dioptre (1)	Accept MP2 if you see $\frac{1}{25}$ or $\frac{1}{2.4}$ for $\frac{1}{f}$ Example of Calculation $\frac{1}{0.25}+\frac{1}{0.024}=46$ D	3

Q3.

Question Number	Answer	Additional Guidance	Mark
	• Use of $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ and $P=\frac{1}{f}$ • Use of $P=P_1+P_2$ • (−) 0.6 D • Diverging	MP4 dependent on MP3 Example of calculation Power of eye $P=\frac{1}{1.5\text{ (m)}}+\frac{1}{0.024\text{(m)}}=42.3$ D P of spectacles = 41.7 (D) – 42.3 (D) = -0.6 D diverging	4

Q4.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Focus image of distant/far object on to a screen (1) • Measure distance from lens to screen (1) **Or** • Use <u>parallel</u> rays of light (1) • Measure distance from lens to the point where the rays converge (1)	MP2 dependent on MP1	**2**
(ii)	• Greater <u>refraction</u> (1) • To converge (parallel) rays at a point closer to the lens (1)		**2**
(iii)	• Photograph 2 has a greater magnification (1) • so v is greater (1) • since u is constant (1) • So f is greater (1) • Hence photograph 2 taken with lens of focal length 200 mm (1)	MP5 dependent on MP2 and MP4	**5**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	• difference in speed for air to cornea much greater than difference in speed from water to cornea **Or** lower refractive index for water to cornea (= 1.03) **(1)** • so less refraction **Or** so power of eye/cornea reduced **Or** so focal length of eye/cornea increased **(1)** • if goggles worn the interface is with air and refraction is as normal **Or** if goggles worn the interface is with air and image focused on retina **(1)**	MP1: Seeing values of refractive index as 1.03 and 1.38 is not enough, a comparison is required.	**3**

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $P = \frac{1}{f}$ • 1220 (mm)	(1) (1)	Example of calculation 0.82 D = $1/f$ f = 1 / 0.82 D = 1.22 m Accept 122 (cm)	2

Q7.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An explanation that makes reference to: **EITHER** • holding the lens steady in your hand would be difficult and would make the distance measurement inaccurate **(1)** • so the lens should be in a holder on a stable surface to make the measurement accurate **(1)** **OR** • holding the ruler steady parallel to the principal axis would be difficult and make the distance measurement inaccurate **(1)** • so the ruler should be on a stable surface to make the measurement accurate **(1)** **OR** • focal length is image distance when object distance is infinite **(1)** • this is not at infinity so lens formula should be used **(1)**	These marks can be awarded only for answers in the context of the method described in the question. Reference to use of an optical bench is acceptable. Reference to use of a clamp is acceptable.	2
(ii)	• use of power = 1/focal length **(1)** • calculates at least two powers correctly **(1)** • analyses data to compare powers or focal lengths **(1)** • draws a conclusion that is consistent with calculated values about how well the relationship is supported **(1)**	This is a comparison, so use of cm not penalised if used for all and unit D is not required. MP3 calculates combined power and uses it to calculate focal length for the combination and compares this with the measured value of focal length. Example of calculation: $P = 1/f$ power $_{lid}$ = 1/0.12 = 8.3 D power $_{optional}$ = 1/0.175 = 5.7 D power $_{combined}$ = 1/0.07 = 14 D 8.3 + 5.7 = 14 D	4

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Q8.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $P = 1/f$ • $f = 8.47$ (mm)	(1) (1)	Example of calculation $f = 1 / 118$ D = 8.47 mm	2
(ii)	• Use of $1/v + 1/u = 1/f$ (allow u and v reversed, but not f) • $u = 14.8$ mm (ecf for f from 19(a)(i))	(1) (1)	Example of calculation 1/20 mm + $1/u$ = 1/8.5 mm $u = 14.8$ mm	2
(iii)	• (Freshwater has a lower refractive index than seawater, so) there will be greater refraction of light on entering the lens • This means that the power of the lens is greater in freshwater **Or** this means that the focal length is less in freshwater • This means that the shortest distance will be decreased	(1) (1) (1)		3
(iv)	• Use of $n = c/v$ • $v = 2.2 \times 10^8$ m s^{-1}	(1) (1)	Example of calculation $1.37 = 3.00 \times 10^8$ m s^{-1} / v $v = 2.2 \times 10^8$ m s^{-1}	2

Q9.

Question Number	Acceptable answers		Additional guidance	Mark
	• use of $P = 1/f$ • use of $P = P_1 + P_2$ etc • total power = 63.8 (D) • Comparative statement consistent with their values	(1) (1) (1) (1)	**MP4** An attempt at a % must be made and a clear comparison with the 80% must be made e.g % for cornea from 44.8 / 63.8 is 71% which is not 80% so no Example of calculation $P_{cornea} = 1/ 0.0223$ m = 44.84 D $P_{lens} = 1/ 0.0527$ m = 18.98 D Total power = 63.82 D	4

Q10.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{image\ height}{object\ height}$ • Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • 21 D (1)	Example of Calculation $m = \frac{3.5\times10^{-3}\ \text{m}}{2.0\times10^{-4}\ \text{m}} = 17.5$ $v = 17.5 \times 5.0 \times 10^{-2}\text{m} = 0.875$ (m) $\frac{1}{f} = \frac{1}{5.0\times10^{-2}\ \text{m}} + \frac{1}{0.875\ \text{m}}$ $f = 0.047$ m $P = \frac{1}{0.047\ \text{m}} = 21.1$ D	5

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • Use of $P = P_1 + P_2 = 5\text{D}$ therefore use one lens with power of 2 (D) and one with power of 3 (D) (1)	Example of Calculation $v = 0.5 \text{ x } 0.6 \text{ m} = 0.3 \text{ m}$ $\frac{1}{f} = \frac{1}{0.6 \text{ m}} + \frac{1}{0.3 \text{ m}}$ $f = 0.2 \text{ m}$ $P = 1/0.2 \text{ m} = 5\text{D}$	4

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	• increases the power (of the eye) **Or** to decrease the image distance **Or** to shorten the focal length (of the eye and lens) **Or** to the eye it makes the rays appear to come from an object further away **(1)**	If a candidate states that the image is formed at the focal point or that the retina is at the focal point do not award this mark	1

Q3.

Question Number	Answer	Additional Guidance	Mark
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ **and** $P = \frac{1}{f}$ • Use of $P = P_1 + P_2$ • (−) 0.6 D • Diverging	MP4 dependent on MP3 Example of calculation Power of eye $P = \frac{1}{1.5 \text{ (m)}} + \frac{1}{0.024 \text{(m)}} = 42.3 \text{ D}$ P of spectacles = 41.7 (D) – 42.3 (D) = -0.6 D diverging	4

Q4.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Focus image of distant/far object on to a screen (1) • Measure distance from lens to screen (1) **Or** • Use <u>parallel</u> rays of light (1) • Measure distance from lens to the point where the rays converge (1)	MP2 dependent on MP1	**2**
(ii)	• Greater <u>refraction</u> (1) • To converge (parallel) rays at a point closer to the lens (1)		**2**
(iii)	• Photograph 2 has a greater magnification (1) • so v is greater (1) • since u is constant (1) • So f is greater (1) • Hence photograph 2 taken with lens of focal length 200 mm (1)	MP5 dependent on MP2 and MP4	**5**

Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An explanation that makes reference to: **EITHER** • holding the lens steady in your hand would be difficult and would make the distance measurement inaccurate **(1)** • so the lens should be in a holder on a stable surface to make the measurement accurate **(1)** **OR** • holding the ruler steady parallel to the principal axis would be difficult and make the distance measurement inaccurate **(1)** • so the ruler should be on a stable surface to make the measurement accurate **(1)** **OR** • focal length is image distance when object distance is infinite **(1)** • this is not at infinity so lens formula should be used **(1)**	These marks can be awarded only for answers in the context of the method described in the question. Reference to use of an optical bench is acceptable. Reference to use of a clamp is acceptable.	**2**
(ii)	• use of power = 1/focal length **(1)** • calculates at least two powers correctly **(1)** • analyses data to compare powers or focal lengths **(1)** • draws a conclusion that is consistent with calculated values about how well the relationship is supported **(1)**	This is a comparison, so use of cm not penalised if used for all and unit D is not required. MP3 calculates combined power and uses it to calculate focal length for the combination and compares this with the measured value of focal length. Example of calculation: $P = 1/f$ power $_{lid} = 1/0.12 = 8.3$ D power $_{optional} = 1/0.175 = 5.7$ D power $_{combined} = 1/0.07 = 14$ D $8.3 + 5.7 = 14$ D	**4**

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of $P = 1/f$ **(1)** • use of $P = P_1 + P_2$ etc **(1)** • total power = 63.8 (D) **(1)** • Comparative statement consistent with their values **(1)**	**MP4** An attempt at a % must be made and a clear comparison with the 80% must be made e.g % for cornea from 44.8 / 63.8 is 71% which is not 80% so no Example of calculation $P_{cornea} = 1/ 0.0223$ m = 44.84 D $P_{lens} = 1/ 0.0527$ m = 18.98 D Total power = 63.82 D	**4**

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is **B** because the power of a diverging lens is negative, so the total power = 9.4 D – 4.2 D = 5.2 D A is not correct because the total power should be obtained from (9.4 D – 4.2 D), but this is (9.4 D + 4.2 D) C is not correct because this is (4.2 D – 9.4 D) using negative power for a converging lens and positive for a diverging lens where it should be the opposite so that (9.4 D – 4.2 D) is used D is not correct because – 13.6 D = – 9.4 D – 4.2 D, as if both lenses are diverging, which is not the case		1

Q8.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	A ray diagram including: • ray from top of object through centre of lens to retina (1) • ray parallel to axis on one side of lens and through focal point on other side (1) • distance to near point = 6.0 cm (1)	Correct calculation scores MP3 only	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• use of $M = v/u$ (1) • M = 0.33 (2/3 sf) ecf u from (i) (1)	<u>Example of calculation</u> M = 2 cm / 6 cm = 0.33	**(2)**

Q9.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Increasing light intensity increases rate of photons/energy arriving at LDR (1) • More electrons gain enough energy to be released/free to conduct (1) • Greater number of conduction electrons per unit volume (1) • $I = nAvq$ so current increases and resistance decreases (1)		4

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • Use of $P = P_1 + P_2 = 5\text{D}$ therefore use one lens with power of 2 (D) and one with power of 3 (D) (1)	Example of Calculation $v = 0.5 \times 0.6\text{ m} = 0.3\text{ m}$ $\frac{1}{f} = \frac{1}{0.6\text{ m}} + \frac{1}{0.3\text{ m}}$ $f = 0.2\text{ m}$ $P = 1/0.2\text{ m} = 5\text{D}$	4

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Light rays pass through the image **Or** Light rays converge to a point where the image is formed (1)		1

Q3.

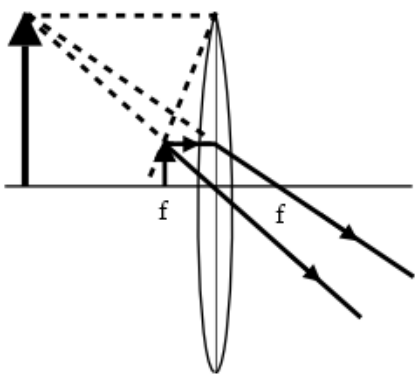
Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Object/star is at infinity, so (intermediate) image formed at focal length of objective lens (1) • (Final image at infinity), so object (intermediate image) must be at focal length of eyepiece lens (1) **Or** • Objective lens, $1/v + 1/u = 1/f$, and u = infinity, so $v = f$ • Eyepiece lens, $1/v + 1/u = 1/f$, v = infinity so $u = f$	Appropriate references to parallel rays may be equivalent to object/image at infinity Example Objective: $1/v + 1/u = 1/f$, $u = \infty$, so $1/v + 1/\infty = 1/f$ $1/v + 0 = 1/f$ $v = f$ Eyepiece: $1/v + 1/u = 1/f$, $v = \infty$, so $1/\infty + 1/u = 1/f$ $0 + 1/u = 1/f$ $u = f$ Note: If both lenses are considered, $1/v + 1/u = 1/f$ does not have to be quoted twice	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• The rays cross over after the objective lens **Or** (1) • The objective lens inverts the image **Or** • The image formed by the eyepiece lens is on the same side as its object, so remains the same way up		1

Q4.

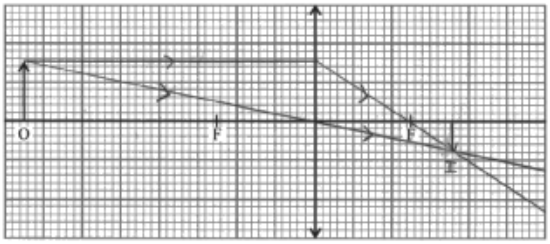
Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is **B** because m is the SI unit for length. A is not correct because C is not a base unit C is not correct because g is not a base unit D is not correct because °C is not a base unit	1

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	Two construction rays from: • ray from tip of object parallel to principal axis drawn then refracted through the focal point **(1)** • ray drawn from tip of object through centre of lens **(1)** • ray drawn from focal point through tip of object and then refracted parallel to the principal axis **(1)** **And** • rays extended back to locate tip of image on the same side as the object **(1)**	Example of diagram:  	3

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $m = v/u$ **(1)** • Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ and substituting for v or u **(1)** • $u = 6.1$ cm **(1)**	Example of calculation: $\frac{v}{u} = -3.5 \quad \therefore v = -3.5u$ $\frac{1}{u}+\frac{1}{-3.5u}=\frac{1}{8.5} \quad \therefore \frac{3.5-1}{3.5u}=\frac{1}{8.5} \quad \therefore \frac{3.5u}{2.5}=8.5$ $u = \frac{8.5\times 2.5}{3.5} = 6.07\,\text{cm}$	**3**

Q6.

Question Number	Acceptable Answers		Additional guidance	
(i)	• One ray correctly drawn • Second ray correctly drawn • Completes diagram with image at position 3.6 to 3.8 cm and height of 0.7 to 0.8 cm	(1) (1) (1)		**3**
(ii)	• Use of $m = \frac{v}{u}$ **or** $m = \frac{image\ height}{object\ height}$ using values from (a)(i) • Magnification of 0.47 to 0.53	(1) (1)	Example of Calculation $m = \frac{v}{u} = \frac{3.7}{7.5} = 0.5$	**2**
(iii)	• Real **and** image on different side of converging lens to object **Or** rays pass through the image	(1)		**1**

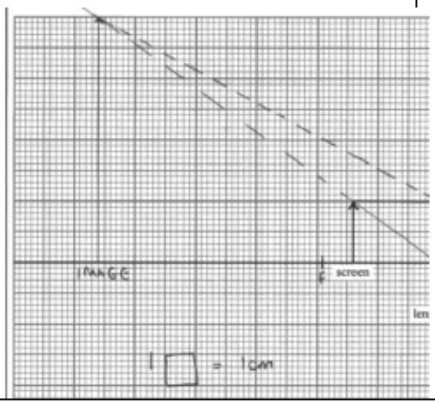
Q7.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Only a real image will be produced on a screen **(1)** • The object cannot be closer than *f* for a real image **(1)** • Because light diverges after passing through the lens **(1)** **OR** • If object closer than *f* rays still diverge after passing though lens **(1)** • So a virtual image is formed **(1)** • which cannot be seen on a screen. **(1)**		**3**

Q8.

Question Number	Answer	Mark
	The only correct answer is C because 10 cm is more than the focal length from a converging lens A diverging lenses do not form real images from real objects B diverging lenses do not form real images from real objects D an object at less than the focal length from a converging lens will form a virtual image	**1**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• Two rays correctly drawn including extrapolation (1) • Completes diagram with image at 10.6 cm (range 9.0 cm to 12.0 cm) (1) • Magnification = 3.8 (3.5 to 4.0) (1) • Conclusion consistent with values for distance and *M* (1)	Acceptable rays: • from arrowhead on object through the optical centre of the lens • from arrowhead on object parallel to the axis up to the lens and then through the principal focus on the other side • from the principal focus on the same side and through the arrowhead on the object to the lens and then parallel to the axis <u>Example of calculation</u> *M* = image size / object size (accept use of distances) = 8.0 cm / 2.0 cm = 4.0 	4

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of lens equation $1/f = 1/v + 1/u$ (1) • Use of magnification = v/u (1) • Magnification = 15 (1)	<u>Example of calculation</u> 1/17.9 mm = 1/*v* + 1/16.7 mm *v* = (-)249 mm magnification = 249 mm / 16.7 mm = 14.9	3

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q13.

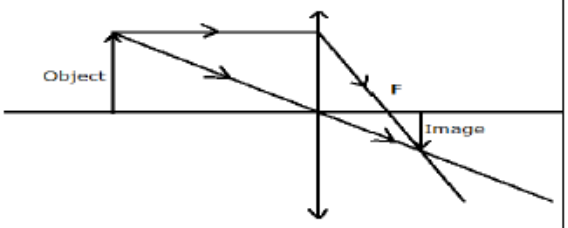
Question Number	Acceptable Answers	Additional guidance	Mark
	• Light is refracted as it passes into medium 2 **(1)** • Angle of refraction may be calculated using $n_1\sin\theta_1 = n_2\sin\theta_2$ **(1)** • Angle of refraction = 89.81° **(1)** • Angle of <u>incidence</u> at layer 2-3 is greater than the critical angle **(1)** • So <u>total internal reflection</u> occurs (at layer 2-3 interface) **(1)** • So light/ rays appear to come from surface of road (so that observer sees mirage) **(1)**	MP2 see use of the equation MP5 accept totally internally reflected and TIR MP6 is not just for saying there is a mirage. <u>Example of Calculation</u> $\sin^{-1}\left(\frac{1.00032 \times \sin 89.59°}{1.00030}\right)$ $= 89.81°$	6

Q14.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	**Either** • Rays from (a point) on the moon are <u>parallel</u> • So the rays converge to the principal focus **Or** so the image is formed at the principal focus **Or** • Use of $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ with $u=\infty$ or very large • $f=v$	(1) (1) (1) (1)	Description of focal length as: the distance between the lens and point at which parallel rays will converge (after passing through lens), scores 2 Accept focal point for principal focus **(MP2 dependent on MP1)** **(MP2 dependent on MP1)**	**2**

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	Real Diminished Inverted	(2)	One/Two properties scores 1 mark Three properties score 2 marks Accept smaller Accept upside down	**2**

Q15.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• use of a correct ray • use of second correct ray • indicates image formed where rays cross • image drawn is real, inverted and diminished	(1) (1) (1) (1)	<u>Correct rays are:</u> Ray through the principal focus and parallel to the principal axis Ray parallel to principal axis then through the principal focus Ray through the optical centre of the lens <u>Example of diagram:</u>  	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• use of $1/f = 1/v + 1/u$ (1) for u estimate 4 – 10 mm • use of $P = 1/f$ (1) • P = (120 D to 230 D) (1)	<u>Example of calculation:</u> Assuming the thickness of 8 mm: $1/f = 1/0.008 + 1/0.045$ $P = 1/f$ P = 147 D Full credit for any thicknesses in range 4 – 10 mm	**(3)**

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • Use of $P = P_1 + P_2 = 5\text{D}$ therefore use one lens with power of 2 (D) and one with power of 3 (D) (1)	Example of Calculation $v = 0.5 \text{ x } 0.6 \text{ m} = 0.3 \text{ m}$ $\frac{1}{f} = \frac{1}{0.6 \text{ m}} + \frac{1}{0.3 \text{ m}}$ $f = 0.2 \text{ m}$ $P = 1/0.2 \text{ m} = 5\text{D}$	4

Q2.

Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is **B** because m is the SI unit for length. A is not correct because C is not a base unit C is not correct because g is not a base unit D is not correct because °C is not a base unit	1

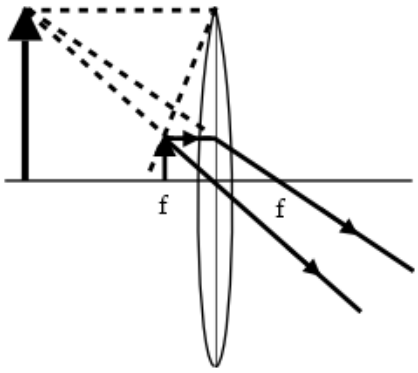
Q3.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ (1) • Use of $P=\frac{1}{f}$ (1) • P = 46 D / Dioptre / dioptre (1)	Accept MP2 if you see $\frac{1}{25}$ or $\frac{1}{2.4}$ for $\frac{1}{f}$ Example of Calculation $\frac{1}{0.25}+\frac{1}{0.024}=46$ D	3

Q4.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• use of $1/v + 1/u = 1/f$ **(1)** • use of magnification = v/u **(1)** • magnification = 3.5 **(1)**	Example of calculation $1/v = 1/7.0 – 1/5.0$ v = 17.5 cm M = 17.5 / 5.0 = 3.5	3

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	Two construction rays from: • ray from tip of object parallel to principal axis drawn then refracted through the focal point **(1)** • ray drawn from tip of object through centre of lens **(1)** • ray drawn from focal point through tip of object and then refracted parallel to the principal axis **(1)** **And** • rays extended back to locate tip of image on the same side as the object **(1)**	Example of diagram:  	3

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $m = v/u$ **(1)** • Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ and substituting for v or u **(1)** • $u = 6.1$ cm **(1)**	Example of calculation: $\frac{v}{u}=-3.5 \quad \therefore v=-3.5u$ $\frac{1}{u}+\frac{1}{-3.5u}=\frac{1}{8.5} \quad \therefore \frac{3.5-1}{3.5u}=\frac{1}{8.5} \quad \therefore \frac{3.5u}{2.5}=8.5$ $u=\frac{8.5\times 2.5}{3.5}=6.07\,\text{cm}$	**3**

Q6.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• drag + weight = upthrust (1) • use of $\rho = m/V$ **and** $W = mg$ (1) • use of $F = 6\pi\eta rv$ **and** $V = 4/3\pi r^3$ (1)	Example of calculation: drag + weight = upthrust drag = upthrust - weight $6\pi\eta rv = 4\pi r^3\rho_{stout}g/3 - 4\pi r^3\rho_{gas}g/3$ $v = 2(\rho_{stout} - \rho_{gas})r^2g/9\eta$	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• low speed OR laminar flow OR not turbulent flow		**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(iii)	• use of $v = 2(\rho_{stout} - \rho_{gas})r^2g/9\eta$ (1) • use of $v = s/t$ (1) • time = 29 s (1) • comment on the difference with 120 seconds OR an attempt to account for the difference (1)	Example of calculation: $v = 2\ (1.007 \times 10^3\ \text{kg m}^{-3} - 1.223\ \text{kg m}^{-3}) \times (61 \times 10^{-6}\ \text{m})^2 \times 9.81\ \text{N kg}^{-1} / 9 \times 2.06 \times 10^{-3}\ \text{Pa s}$ $= 3.96 \times 10^{-3}\ \text{m s}^{-1}$ $t = 0.115\ \text{m} / 3.96 \times 10^{-3}\ \text{m s}^{-1}$ $= 29\ \text{s}$ Actual time much less than the manufacturers time therefore not a valid statement OR reference time to reach terminal velocity OR there is turbulent flow	**(4)**

Q7.

Question Number	Answer	Additional Guidance	Mark
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and $P = \frac{1}{f}$ • Use of $P = P_1 + P_2$ • (−) 0.6 D • Diverging	MP4 dependent on MP3 Example of calculation Power of eye $P = \frac{1}{1.5\text{ (m)}} + \frac{1}{0.024\text{(m)}} = 42.3$ D P of spectacles = 41.7 (D) – 42.3 (D) = -0.6 D diverging	4

Q8.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Focus image of distant/far object on to a screen (1) • Measure distance from lens to screen (1) **Or** • Use parallel rays of light (1) • Measure distance from lens to the point where the rays converge (1)	MP2 dependent on MP1	2
(ii)	• Greater refraction (1) • To converge (parallel) rays at a point closer to the lens (1)		2
(iii)	• Photograph 2 has a greater magnification (1) • so v is greater (1) • since u is constant (1) • So f is greater (1) • Hence photograph 2 taken with lens of focal length 200 mm (1)	MP5 dependent on MP2 and MP4	5

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $m = \frac{\text{image height}}{\text{object height}}$ **(1)** • Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ **(1)** • $\therefore v = 28$ m **(1)**	For MP2 allow ($u \approx f$, so) $v = f \times$ magnification Example of calculation $\frac{v}{u}=\frac{h_i}{h_o}=\frac{0.75\text{ m}}{4.0\times10^{-3}\text{m}}=187.5$ $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ $\therefore \frac{v}{u}+1=\frac{v}{f}$ $\therefore v=(187.5+1)\times15.0\times10^{-2}\text{m}=28.3$ m	**3**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• difference in speed for air to cornea much greater than difference in speed from water to cornea **Or** lower refractive index for water to cornea (= 1.03) **(1)** • so less refraction **Or** so power of eye/cornea reduced **Or** so focal length of eye/cornea increased **(1)** • if goggles worn the interface is with air and refraction is as normal **Or** if goggles worn the interface is with air and image focused on retina **(1)**	MP1: Seeing values of refractive index as 1.03 and 1.38 is not enough, a comparison is required.	**3**

Q11.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • $f = 8.0 \times 10^{-2}$ m (1)	Example of calculation $\frac{1}{f} = \frac{1}{0.09\ \text{m}} + \frac{1}{0.75\ \text{m}}$ $f = 8.00 \times 10^{-2}$m	2

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ (1) • … with consistent units for u and f (1) • Use of displacement = $v - f$ (1) • Displacement of lens = 0.07 mm away from sensor (1)	Example of calculation $\frac{1}{25 \times 10^{-2}\ \text{m}} + \frac{1}{v} = \frac{1}{4.25 \times 10^{-3}\ \text{m}}$ $\therefore \frac{1}{v} = (235.3 - 4)\ \text{m}^{-1}$ $\therefore v = \frac{1}{231.3\ \text{m}^{-1}} = 4.32 \times 10^{-3}\ \text{m}$ Displacement of lens = (4.32 – 4.25) mm = 0.0735 mm	4

Q13.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $P = 1/f$ • $f = 8.47$ (mm)	(1) (1)	Example of calculation $f = 1 / 118$ D = 8.47 mm	2
(ii)	• Use of $1/v + 1/u = 1/f$ (allow u and v reversed, but not f) • $u = 14.8$ mm (ecf for f from 19(a)(i))	(1) (1)	Example of calculation 1/20 mm + $1/u$ = 1/8.5 mm u = 14.8 mm	2
(iii)	• (Freshwater has a lower refractive index than seawater, so) there will be greater refraction of light on entering the lens • This means that the power of the lens is greater in freshwater **Or** this means that the focal length is less in freshwater • This means that the shortest distance will be decreased	(1) (1) (1)		3
(iv)	• Use of $n = c/v$ • $v = 2.2 \times 10^8$ m s^{-1}	(1) (1)	Example of calculation $1.37 = 3.00 \times 10^8$ m s^{-1} / v $v = 2.2 \times 10^8$ m s^{-1}	2

Q14.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ with $u = 100$ and $v = (-)300$ • $f = 150$ (mm) • converging lens with focal length 150 mm	(1) (1) (1)	**(MP3 dependent on MP2)** Example of calculation $\frac{1}{f} = \frac{1}{100\text{ mm}} - \frac{1}{300\text{ mm}}$ $\frac{1}{f} = \frac{3-1}{300\text{ mm}}$ $f = 150$ mm MP3 accept if annotated in question Accept convex for converging	3

Q15.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• use of $1/v + 1/u = 1/f$ **and** $P = 1/f$ to determine power required	(1)	Example of calculation $1/f = 1/0.02$ cm + $1/0.275$ cm $f = 0.0186$ cm $P = 1/f = 53.6$ D For person, $P = 1/0.0193$ $= 51.81$	
	• use of $P = 1/f$ to determine power of person's lens	(1)	Spectacle power = 53.63 – 51.81 = 1.82 D Choose +2.0 D	
	• use of $P = P_1 + P_2$ to determine additional power required	(1)		
	• $P = 1.82$ (D)	(1)		**(4)**

Q16.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• use of $1/f = 1/u + 1/v$ • $u = 4.8$ cm	(1) (1)	Example of calculation 1/1.6 cm = $1/u$ + 1/ 2.4 cm $u = 4.8$ cm	2

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• use of $n = c / v$ • use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **Or** $n = \sin i / \sin r$ with correct angles • $\theta = 11°$	(1) (1) (1)	Accept use of $v_2 \sin\theta_1 = v_1 \sin\theta_2$ for MP1 and MP2 but $v_1 \sin\theta_1 = v_2 \sin\theta_2$ scores neither Example of calculation $n = 3 \times 10^8$ m s^{-1} / 2.18×10^8 m s^{-1} $= 1.376$ $1 \times \sin 15° = 1.376 \times \sin\theta$ $\theta = 10.8°$	3

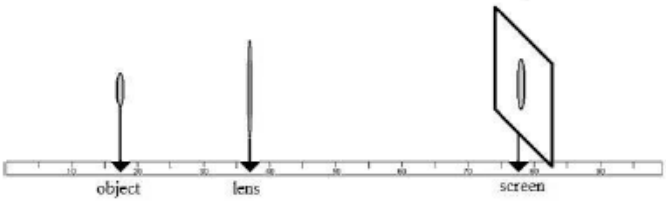
Q17.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of lens equation $1/f = 1/v + 1/u$ • Use of magnification = v/u • Magnification = 15	(1) (1) (1)	Example of calculation 1/17.9 mm = $1/v$ + 1/16.7 mm v = (-)249 mm magnification = 249 mm / 16.7 mm = 14.9	3

Q18.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{image\ height}{object\ height}$ • Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • 21 D (1)	Example of Calculation $m = \frac{3.5\times10^{-3}\ m}{2.0\times10^{-4}\ m} = 17.5$ $v = 17.5 \times 5.0 \times 10^{-2} m = 0.875$ (m) $\frac{1}{f} = \frac{1}{5.0\times10^{-2}\ m} + \frac{1}{0.875\ m}$ $f = 0.047$ m $P = \frac{1}{0.047\ m} = 21.1$ D	5

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• diagram with illuminated object, lens, screen and metre rule (1) • lens position adjusted until clear image located on screen (1) • object, image distances calculated from metre rule readings (1) • procedure repeated for at least 4 other positions of the lens (1)	Example of Diagram:  Example of calculation: $\frac{1}{u} = -\frac{1}{v} + \frac{1}{f}$ $y = mx + c$	**(4)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• $1/v$ plotted against $1/u$ and intercept(s) of line read off (1) • lens equation compared with equation of a straight line (1) • f = 1/intercept (1)	Question 5 to be marked holistically	**(3)**

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	A ray diagram including: • ray from top of object through centre of lens to retina (1) • ray parallel to axis on one side of lens and through focal point on other side (1) • distance to near point = 6.0 cm (1)	Correct calculation scores MP3 only	**(3)**

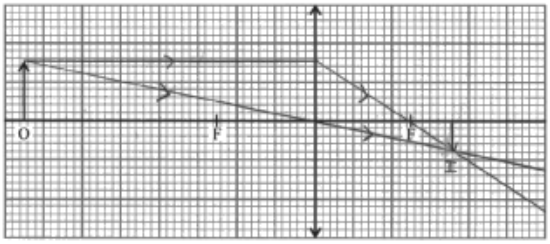
Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• use of $M = v/u$ (1) • M = 0.33 (2/3 sf) ecf u from (i) (1)	<u>Example of calculation</u> M = 2 cm / 6 cm = 0.33	**(2)**

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• use of $1/v + 1/u = 1/f$ **(1)** • use of magnification = v/u **(1)** • magnification = 3.5 **(1)**	Example of calculation $1/v = 1/7.0 – 1/5.0$ $v = 17.5$ cm $M = 17.5 / 5.0 = 3.5$	**3**

Q2.

Question Number	Acceptable Answers	Additional guidance	
(i)	• One ray correctly drawn (1) • Second ray correctly drawn (1) • Completes diagram with image at position 3.6 to 3.8 cm and height of 0.7 to 0.8 cm (1)		**3**
(ii)	• Use of $m = \frac{v}{u}$ **or** $m = \frac{image\ height}{object\ height}$ using values from (a)(i) (1) • Magnification of 0.47 to 0.53 (1)	Example of Calculation $m = \frac{v}{u} = \frac{3.7}{7.5} = 0.5$	**2**
(iii)	• Real **and** image on different side of converging lens to object **Or** rays pass through the image (1)		**1**

Q3.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• drag + weight = upthrust (1) • use of $\rho = m/V$ **and** $W = mg$ (1) • use of $F = 6\pi\eta rv$ **and** $V = 4/3\pi r^3$ (1)	Example of calculation: drag + weight = upthrust drag = upthrust - weight $6\pi\eta rv = 4\pi r^3\rho_{stout}g/3 - 4\pi r^3\rho_{gas}g/3$ $v = 2(\rho_{stout} - \rho_{gas})r^2g/9\eta$	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• low speed OR laminar flow OR not turbulent flow		**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(iii)	• use of $v = 2(\rho_{stout} - \rho_{gas})r^2g/9\eta$ (1) • use of $v = s/t$ (1) • time = 29 s (1) • comment on the difference with 120 seconds OR an attempt to account for the difference (1)	Example of calculation: $v = 2\ (1.007 \times 10^3\ kg\ m^{-3} - 1.223\ kg\ m^{-3}) \times (61 \times 10^{-6}\ m)^2 \times 9.81\ N\ kg^{-1} / 9 \times 2.06 \times 10^{-3}$ Pa s $= 3.96 \times 10^{-3}\ m\ s^{-1}$ $t = 0.115\ m / 3.96 \times 10^{-3}\ m\ s^{-1}$ $= 29\ s$ Actual time much less than the manufacturers time therefore not a valid statement OR reference time to reach terminal velocity OR there is turbulent flow	**(4)**

Q4.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Focus image of distant/far object on to a screen (1) • Measure distance from lens to screen (1) **Or** • Use parallel rays of light (1) • Measure distance from lens to the point where the rays converge (1)	MP2 dependent on MP1	**2**
(ii)	• Greater refraction (1) • To converge (parallel) rays at a point closer to the lens (1)		**2**
(iii)	• Photograph 2 has a greater magnification (1) • so v is greater (1) • since u is constant (1) • So f is greater (1) • Hence photograph 2 taken with lens of focal length 200 mm (1)	MP5 dependent on MP2 and MP4	**5**

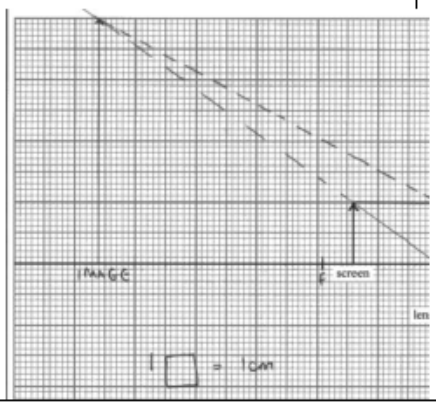
Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $m = \frac{\text{image height}}{\text{object height}}$ **(1)** • Use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ **(1)** • $\therefore v = 28$ m **(1)**	For MP2 allow ($u \approx f$, so) $v = f \times$ magnification Example of calculation $\frac{v}{u}=\frac{h_i}{h_o}=\frac{0.75\text{ m}}{4.0\times10^{-3}\text{m}}=187.5$ $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ $\therefore \frac{v}{u}+1=\frac{v}{f}$ $\therefore v=(187.5+1)\times15.0\times10^{-2}\text{m}=28.3$ m	**3**

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is **D** because magnification is numerically equal to image distance divided by object distance A is not correct because magnification is numerically equal to image distance divided by object distance, but this is focal length divided by object distance B is not correct because magnification is numerically equal to image distance divided by object distance, but this is object distance divided by image distance C is not correct because magnification is numerically equal to image distance divided by object distance, but this is object distance divided by focal length		1

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• Two rays correctly drawn including extrapolation (1) • Completes diagram with image at 10.6 cm (range 9.0 cm to 12.0 cm) (1) • Magnification = 3.8 (3.5 to 4.0) (1) • Conclusion consistent with values for distance and *M* (1)	Acceptable rays: • from arrowhead on object through the optical centre of the lens • from arrowhead on object parallel to the axis up to the lens and then through the principal focus on the other side • from the principal focus on the same side and through the arrowhead on the object to the lens and then parallel to the axis <u>Example of calculation</u> *M* = image size / object size (accept use of distances) = 8.0 cm / 2.0 cm = 4.0 	4

Q8.

Question Number	Answer	Mark
	C - 1.5	**1**
	Incorrect Answers: all select incorrect data from question Correct method: image distance ÷ object distance A – uses focal length ÷ object distance B – uses object distance ÷ image distance D – uses object distance ÷ focal length	

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of lens equation $1/f = 1/v + 1/u$ **(1)** • Use of magnification = v/u **(1)** • Magnification = 15 **(1)**	Example of calculation 1/17.9 mm = 1/v + 1/16.7 mm v = (-)249 mm magnification = 249 mm / 16.7 mm = 14.9	**3**

Q10.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{v}{u}$ (to calculate m) (1) • Use of $m = \frac{\text{image height}}{\text{object height}}$ to calculate distance between dots on screen (1) • Uses tan/sin **or** small angle approximation to calculate the angle (1) • Answer consistent with their calculation (1) • Comparison with 0.0003 radians **or** 0.017° and conclusion consistent with their value for θ (1)	Example of calculation $m = \frac{0.75\text{ m}}{0.09\text{ m}} = 8.3$ Image height = 8.3 x 0.005 m = 0.042 (m) $\tan(\frac{\theta}{2}) = \frac{0.042/_2\text{ m}}{4.5\text{ m}}$ $\theta = 0.5° = \frac{0.5\pi}{180}$ rads = 0.0092radians 0.009 radians > 0.0003 radians so student can distinguish between the dots	5

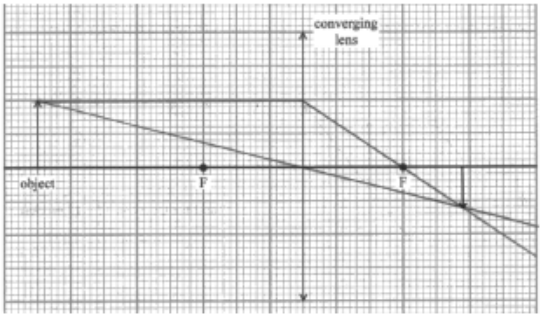
Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q12.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $m = \frac{image\ height}{object\ height}$ • Use of $m = \frac{v}{u}$ (1) • Use of $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ (1) • Use of $P = \frac{1}{f}$ (1) • 21 D (1)	Example of Calculation $m = \frac{3.5\times10^{-3}\text{ m}}{2.0\times10^{-4}\text{ m}} = 17.5$ $v = 17.5 \times 5.0 \times 10^{-2}\text{m} = 0.875$ (m) $\frac{1}{f} = \frac{1}{5.0\times10^{-2}\text{ m}} + \frac{1}{0.875\text{ m}}$ $f = 0.047$ m $P = \frac{1}{0.047\text{ m}} = 21.1$ D	5

Q13.

Question Number	Answer	Additional Guidance	Mark
	• two rays correctly drawn (1) • image drawn in correct position ±half square (1) • use of $m = \frac{v}{u}$ or $m = \frac{image\ height}{object\ height}$ (1) • m = 0.6 (1)	 Example of calculation $m = \frac{4.8\ \text{cm}}{8.0\ \text{cm}} = 0.6$	4

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
	• Pass light through one lens of the glasses and view the light through the lens of the second pair of glasses. Rotate one pair of glasses through 90° **(1)** • If the light intensity varies then the glasses use polarising filters **(1)**	Allow full credit for a suitably annotated diagram.	2

Q15.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</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><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></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></td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
<tr><td>* (continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.

<table><tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></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></td><td></td><td></td></tr>
</table>

Question Number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • a polarising filter restricts the (electric field) vibrations of the (transverse) light wave to a single plane • including the direction of propagation of the light • the light incident on the filter must be plane polarised • when the angle of rotation is a multiple of π rad (including zero), the plane of polarisation of the incident light is perpendicular to the transmission axis of the polarising filter hence the intensity of the transmitted light is zero • when the angle of rotation is an odd multiple of π/2 rad the plane of polarisation of the incident light is the same as that of the transmission axis of the polarising filter hence maximum light is transmitted • the intensity of the transmitted light varies from a minimum to a maximum as the angle of rotation varies as shown by the graph		

Question Number	Acceptable answers	Additional guidance	Mark
* (continued)	**Alternative answer** • a polarising filter restricts the (electric field) vibrations of the (transverse) light wave to a single direction • perpendicular to the direction of propagation of the light • the light incident on the filter is plane polarised • when the angle of rotation is a multiple of π rad (including zero), the plane of polarisation of the incident light is perpendicular to the transmission axis of the polarising filter hence the intensity of the transmitted light is zero • when the angle of rotation is an odd multiple of π/2 rad the plane of polarisation of the incident light is the same as that of the transmission axis of the polarising filter hence maximum light is transmitted • the intensity of the transmitted light varies from a minimum to a maximum as the angle of rotation varies as shown by the graph		