3. Waves

3.2 Light

Paper 3 and 4

Answer Key

Paper 3

Q1.

Question	Answer	Marks
(a)(i)	0.11 (m)	**B1**
(a)(ii)	0.08 (m)	**B1**
(a)(iii)	any **two** from: • diminished OR smaller • inverted OR upside down • real	**B2**
(b)(i)	X (–rays) (*box on left*)	**B1**
	gamma (rays / radiation) (*box on right*)	**B1**
(b)(ii)	security marker OR detecting fake bank notes OR sterilising (medical instruments / water / food)	**B1**
(b)(iii)	damage to skin OR (surface) cells OR eyes	**B1**

Q2.

Question	Answer	Marks
(a)(i)	angle of reflection identified	**B1**
(a)(ii)	40 (°)	**B1**
(b)(i)	horizontal ray drawn to continue through F_2	**B1**
	ray to centre drawn to continue undeviated	**B1**
(b)(ii)	(image drawn / identified) where rays cross	**B1**
(c)(i)	dispersion	**B1**
(c)(ii)	all 7 colours **AND** in correct order	**A2**
	6 of the seven colours given	(C1)

Q3.

Question	Answer	Marks
(a)	7 (cm)	**B1**
(b)	arrow drawn (perpendicularly) from principal axis to intersection of rays.	**B1**
(c)	(image is) real	**B1**
	inverted	**B1**

Q4.

Question	Answer	Marks
(a)	top diagram ---------- diffraction	B1
	bottom diagram ---------- refraction	B1
(b)(i)	principal axis	B1
(b)(ii)	principal focus	B1
(b)(iii)	vertical line from point where rays cross to the principal axis	B1
(b)(iv)	1.9 (cm)	B1
(b)(v)	enlarged ✓ diminished same size inverted ✓ upright virtual real ✓	B1 B1 B1

Q5.

Question	Answer	Marks
(a)	**both** rays refracted toward principal axis	B1
	both rays meet at F_1	B1

Q6.

Question	Answer	Marks
(a)(i)	refraction	B1
(a)(ii)	any **two** from: • wavelength • speed • direction	B2
(b)	total internal reflection	B1
	(red light) travelling from more dense **OR** into / towards less dense (medium)	B1
	incident on surface at an angle / angle of incidence greater than critical angle	B1

Q7.

Question	Answer	Marks
(a)(i)	normal (line)	B1
(a)(ii)	correct angle clearly indicated	B1
(a)(iii)	angle of incidence = angle of reflection	B1
(b)	same size	B1
	upright	B1
(c)(i)	single ray with correct refraction in glass	B1
	emergent ray with correct refraction	B1
(c)(ii)	refraction	B1

Q8.

Question	Answer	Marks
(a)(i)	29(°)	B1
(a)(ii)	normal (line)	B1
(b)(i)	ray through centre continues in straight line	B1
	(ray through F) drawn parallel to principal axis	B1
(b)(ii)	arrow drawn from principal axis to where rays cross	B1

Q9.

Question	Answer	Marks
(a)(i)	ray drawn refracted away from normal	B1
(a)(ii)	angle of incidence correctly identified	B1
(a)(iii)	angle of refraction correctly identified	B1
(b)	total internal reflection (at flat surface)	B1
	angle (of incidence) is greater than the critical angle	B1

Q10.

Question	Answer	Marks
(a)(i)	b	B1
(a)(ii)	c	B1
(b)	ray from lamp extended to mirror as straight line (by eye)	M1
	ray reflected to car B	A1

Q11.

Question	Answer	Marks
(a)(i)	normal drawn at X correct by eye	B1
(a)(ii)	angle of refraction correctly labelled	B1

Question	Answer	Marks
(a)(iii)	any **one** from: • pin(s) OR ray box owtte OR (low voltage) power supply OR • protractor OR ruler	B1
(b)	ray reflected from flat surface	M1
	ray reflected with angle *i* = angle *r*	A1

Q12.

Question	Answer	Marks
(a)(i)	50°	B1
(a)(ii)	normal correctly positioned	B1
	correct reflected ray at 50° to normal	B1
(b)(i)	12 (cm)	B1
(b)(ii)	21 (cm)	B1
(b)(iii)	inverted	B1
	smaller / diminished	B1

Q13.

Question	Answer	Marks
(a)	8.5 to 9.1 squares counted	C1
	4.5 (cm)	A1
(b)(i)	focal length marked from centre of lens	B1
	to point where ray parallel to axis is refracted by lens to cross axis	B1
(b)(ii)	inverted (third word circled)	B1
	diminished (5th / last word circled)	B1

Q14.

Question	Answer	Marks
(a)(i)	60(°)	B1
(a)(ii)	normal correctly positioned	B1
	correct reflected ray at 60° to normal	B1
	same value as (i)	B1
(b)	horizontal ray drawn to continue through F	B1
	ray through principal focus continues parallel to axis	B1
	image indicated in correct position	B1
	image indicated with correct orientation	B1

Q15.

Question	Answer	Marks
(a)(i)	normal	B1
(a)(ii)	p	B1
(a)(iii)	r	B1
(a)(iv)	speed decreases	B1

Question	Answer	Marks
(b)	reflects off flat surface at same angle (by eye)	B1
	passes through curved surface without deviation	B1
(c)(i)	D – total internal reflection	B1
(c)(ii)	E – dispersion	B1
(c)(iii)	F – spectrum of visible light	B1

Q16.

Question	Answer	Marks
(a)(i)	straight line to mirror **AND** normal correctly positioned	B1
(a)(ii)	two correct reflections drawn	B1
(a)(iii)	angle of incidence = angle of reflection	B1
(b)	refracted away from normal	B1
	refracted along straight edge	B1
	totally internally reflected	B1

Q17.

Question	Answer	Marks
(a)(i)	ray from X through centre of lens	B1
(a)(ii)	image drawn from axis to point where rays cross and labelled I	B1
(a)(iii)	point labelled F where ray crosses principal axis	B1
(a)(iv)	2.7 (cm) ± 0.2 cm	B1
(b)	diminished 2nd box ticked	B1
	inverted 4th box ticked	B1

Q18.

Question	Answer	Marks
(a)	top box ticked C to F_1	B1
(b)	Diagonal ray through F1 to lens then parallel to optical axis to I.	B1
	ray parallel to principal axis to lens then refracted through F_2 to I	B1
	both rays meet at arrowhead of image	B1
(c)	(image) closer (to lens / F_2) owtte (image) smaller	B1 B1

Q19.

Question	Answer	Marks
(a)(i)	normal	B1
(a)(ii)	(angle of) incidence	B1
(a)(iii)	double(s)	B1
(b)(i)	principal focus	B1
(b)(ii)	inverted diminished	B2

Q20.

Question	Answer	Marks
(a)(i)	refracted at first boundary correctly	B1
	refracted at second boundary correctly	B1
(a)(ii)	refraction	B1
(b)(i)	converging / bent inwards / meet at a point e.g. focus	B1
(b)(ii)	two straight rays drawn converging	B1

Q21.

Question	Answer	Marks
(a)(i)	blue between indigo and green	1
	yellow between green and orange	1
(a)(ii)	arrow pointing right ⟶	1
(b)(i)	ray(s) refracted down at first boundary (air/glass)	1
	correct refraction for candidate's ray (in glass prism)	1
(b)(ii)	refraction	1

Q22.

Question	Answer	Marks
(a)	(focal length =) 5 (cm)	1
(b)(i)	straight line through F and then parallel to PA from centre of lens	1
(b)(ii)	straight line from top of object through centre of lens	1
(b)(iii)	image indicated at point where rays cross	1
	arrow drawn inverted on RHS of lens	1

Paper 4

Q23.

Question	Answer	Marks
(a)(i)	(point on principal axis) where rays of light parallel (to the principal axis, incident on converging lens)	**B1**
	(rays) meet / converge after passing through lens / refraction	**B1**
(a)(ii)	X marked between one of the focal points and the lens **AND** E marked on other side of lens	**B1**
(a)(iii)	virtual **AND** upright	**B1**
(b)(i)	2.0×10^8 m / s	**A2**
	$n = c / v_g$ **OR** (v_g =) c / n **OR** (v_g =) $3(.0) \times 10^8 / 1.5$	C1
(b)(ii)	(wavelength) decreases	**B1**
(c)	long-sightedness	**B1**
	it moves the image towards the lens / back of the eye / retina **OR** reduces / shortens focal length of (combined lens)	**B1**
	(converging lens) focuses image on back of eye / retina	**B1**

Q24.

Question	Answer	Marks
(a)	ray travels along the normal **OR** angle of incidence = 0(°)	**B1**
(b)(i)	$n = 1 / \sin c$ **OR** (n =) $1 / \sin c$ **OR** (n =) $1 / \sin 42$ (°)	**M1**
	1.5	**A1**
(b)(ii)	ray reflected at BC **AND** no refracted ray	**M1**
	ray hits AC with angle of incidence = 0 °	**A1**
	correct refraction of candidate's ray into air at AC	**B1**

Question	Answer	Marks
(c)	any **two** from: • high rates (of data transmission) / fast (data transmission) • carry large amounts (of data / information) • secure • little signal / data loss • glass is transparent to (some) infrared	**B2**

Q25.

Question	Answer	Marks
(a)(i)	any **two** from: • ray from top / bottom of object, parallel to principal axis, refracted through right-hand principal focus • straight ray from same point on object through optical centre • ray that (seems to) come from left-hand principal focus through same point of object and refracted parallel to principal axis	**M2**
	rays traced back to intersection **AND** intersection / image labelled I	**A1**
(a)(ii)	(distance =) 35.5 cm to 38.5 cm	**A2**
	7.1 to 7.7 (cm) **OR** (distance =) 35.0 (cm) to 40.0 (cm)	C1
(b)	virtual **AND** *any one from:* • cannot be projected on a screen • (real) light (ray) does not pass through image • light only seems to come from image	**B1**
(c)	*any one from:* • long-sightedness focuses image behind retina / back of eye **OR** longsightedness produces blurry / fuzzy images (of close objects) • converging lens reduces focal length (of eye) • (converging lens) puts image further away (from the eye)	**B1**
	(converging lens gives) sharp/focussed image on retina / back of eye **OR** (with lens) rays converge on retina / back of eye	**B1**

Q26.

Question	Answer	Marks
(a)	indication of position of car along a straight line from X above and to left of road at junction.	**B1**
(b)	Incident ray from car to mirror **AND** reflected ray from mirror towards X	**B1**
	angle of incidence equal to angle of reflection	**B1**
(c)	converging lens (to left of eye)	**M1**
	rays refracted by additional converging lens	**A1**
	rays refracted by lens in eye to give converging rays	**B1**
	focal point of rays / image on retina	**B1**

Q27.

Question	Answer	Marks
(a)	(light / electromagnetic radiation) of a single frequency	**B1**
(b)	angle of incidence / i = 0 **OR** incident ray along normal **OR** all of wavefront enters block at same time	**B1**
	angle of refraction / r = 0 **OR** no refraction **OR** whole wavefront slows down at same time	**B1**
(c)	(c =) $\sin^{-1}\{1/1.5\}$ (= 42°) **OR** (c =) $\sin^{-1}\{1/n\}$ = 41.8°	**A2**
	$n = 1/\sin c$ **OR** (c =) $\sin^{-1}\{1/n\}$ **OR** (c =) 41.8°	C1
(d)(i)	all light is reflected	**B1**
	θ / angle of incidence > c / critical angle	**B1**
(d)(ii)	all light is reflected **OR** reflected ray at 90° to incident ray **OR** reflected ray is parallel to original ray	**B1**

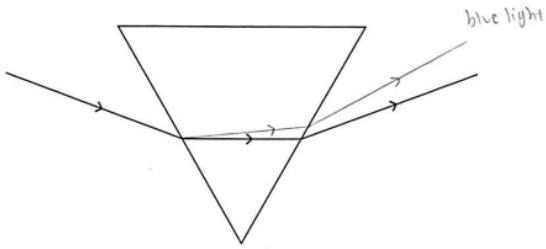
Q28.

Question	Answer	Marks
(a)	normal drawn in correct position and at right angles to the surface	**B1**
(b)	22°	**A3**
	i = 34(°)	C1
	$n = \sin i / \sin r$ **OR** (r =) $\sin^{-1}\{\sin i / n\}$ **OR** $\sin r = \sin 34 / 1.47$ **OR** $\sin r = 0.38$	C1
(c)	3.0×10^8 m / s	**B1**
(d)	2.04×10^8 m / s	**A2**
	n = speed of light in air / speed of light in oil **OR** (speed of light in oil =) speed of light in air / n **OR** (speed of light in oil =) $3.0 \times 10^8 / 1.47$	C1

Q29.

Question	Answer	Marks
(a)	(light of a) single frequency	**B1**
(b)(i)		**B2**
	angle of incidence is 0° (hence) angle of refraction is 0°	B1
	or all the wavefront hits the plastic at the same time all slows down at the same time	B1
(b)(ii)	1.8×10^8 m / s	**A4**
	$n = 1 / \sin c$ in any form **or** $n = 1 / \sin 37°$	C1
	(n =) 1.7	C1
	$v_{pl} = v_0 / n$ in any form **or** $3.0 \times 10^8 / 1.7$ **or** $3.0 \times 10^8 \times \sin 37°$	C1
(b)(iii)		**B3**
	critical angle (for blue light) < 37° **or** critical angle for red (light) is 37°	B1
	angle of incidence (of blue light) greater than its critical angle (in plastic)	B1
	total internal reflection **or** all the (blue) light reflects **or** no (blue) light leaves the glass / refracts / travels in air along the straight edge	B1

Q30.

Question	Answer	Marks
(a)(i)	*two correct rays from*: • ray from X through centre of lens • ray from X to lens, parallel to principal axis, refracted through RH focus F • ray from X (that would pass through LH focus) refracted parallel to principal axis.	**M2**
	two rays correctly extended back, intersecting to left of object and image labelled	**A1**
	IY drawn **AND** 36 mm ≤ distance ≤ 44 mm	**A1**
(a)(ii)	*any two from:* • object closer to lens than (one) focal length • (actual) rays do not meet (at image) • image cannot be formed on a screen **OR** image only visible through lens • object and image on same side (of lens) **OR** image on LHS of lens/object.	**B2**
(b)		**A3**
	blue ray refracted <u>closer</u> to the normal than the green ray as it enters the prism	C1
	blue ray refracted away from the normal as it leaves the prism	C1

Q31.

Question	Answer	Marks
(a)	(all the light) meets (at a point) **or** is focused **or** intersects	**A2**
	(all the light) travels towards a point	C1
	it then diverges or spreads out (from that point) **or** point of convergence is on XY / at F / the focal point / principal focus / 3.0 cm from lens	**B1**
(b)	**two** marked points on XY 3.0 cm from centre of lens **and** one on left and one on right **and** each labelled F	**B1**

Question	Answer	Marks
(c)(i)	**two** of these rays from tip of N drawn: ray (that seems to come) from left-hand principal focus **and** emerges from lens paraxially paraxial ray to lens **and** then towards right-hand principal focus ray towards / through centre of lens	**M2**
	two rays traced back to intersection **and** line from intersection to axis **and** line labelled I	**A1**
(c)(ii)	virtual **and** light / rays do not pass through I **or** virtual **and** light / rays only seem to come from I **or** virtual **and** produced by diverging rays virtual **and** (real) rays do not meet	**B1**
(c)(iii)	magnifying glass	**B1**

Q32.

Question	Answer	Marks
(a)	1.9–2.1 cm	**B1**
(b)	(circle round) enlarged	**B1**
	(circle round) inverted	**B1**
	(circle round) real	**B1**
(c)	not an intersection of rays OR cannot be formed on a screen OR cannot be projected on a screen OR light rays do not pass through image OR light rays do not meet OR light rays do not converge	**B1**

Q33.

Question	Answer	Marks
(a)	(point) where (parallel) rays (of light) meet (after passing through lens)	C1
	point) where parallel rays (of light) meet / are focussed (after passing through lens) **or** (point) through which rays (of light) that emerge parallel pass (before reaching lens)	A1
(b)	distance between principal focus / focal point and optical centre / lens	B1
(c)(i)	vertical line labelled L 4.0 (± 0.2) cm to the right of O	B1
(c)(ii)	paraxial ray from tip of O to candidate's lens **and** from lens to tip of I **or** paraxial ray from lens to tip of I **and** from tip of O to candidate's lens	C1
	3.0 (± 0.2) cm	A1
(c)(iii)	fourth box ticked i.e: 	B1
	reversed / inverted	B1

Q34.

Question	Answer	Marks
(a)(i)	$i = 60°$ used or seen	C1
	sin i / sin $r = n$ in any form	C1
	ray refracted toward normal and toward AC	C1
	ray clearly refracted down in prism reaching AC with r = 35(°)	A1
(a)(ii)	10°	B1
(b)	refracted away from normal	B1
(c)(i)	(total internal) reflection at X NOT refraction at X or anywhere else	B1
	reaches end of fibre with only one additional reflection (off lower internal edge of fibre)	B1
(c)(ii)	total internal reflection	B1

Q35.

Question	Answer	Marks
(a)	blue ray refracted MORE towards normal at first surface	B1
	refraction away from normal at second surface	B1
	ray of blue light below ray of green light and diverging throughout path (after entering prism)	B1
(b)	$v = f\lambda$ in any form OR (f=) v / λ	C1
	(f =) $3 \times 10^8 \div 4.8 \times 10^{-7}$	C1
	(f =) 6.3×10^{14} Hz	A1

Q36.

Question	Answer	Marks
(a)(i)	wave / light / energy / ray is completely / entirely reflected (at the boundary between two mediums) **or** no refraction **or** no wave / light / energy / ray passes into second medium / across boundary **or** only reflection occurs	**B1**
(a)(ii)	light (must pass) from medium where it travels slower **or** to medium where it is faster **or** from medium with larger refractive index **or** to medium with smaller refractive index	**B1**
	angle of incidence (must be) greater than the critical angle / $\sin^{-1}(1 \div n)$	**B1**
(b)	light / infrared travels in fibre	**B1**
	total internal reflection at inner surface **or** within (graded-index) fibre	**B1**
	light carries information / signal / data / message or signal / light encoded	**B1**

Q37.

Question	Answer	Marks
(a)(i)	total internal reflection OR T.I.R.	**B1**
(a)(ii)	sin $C = 1 \div n$ in any form OR (C =) $\sin^{-1}\{1 \div 1.4\}$	**C1**
	($C = \sin^{-1}\{1 \div 1.4\} = \sin^{-1} 0.714$ =) 46°	**A1**
(b)	description of fibre passing to site to be examined / treated	**B1**
	light passes down fibre (to site) AND (image) returns (to sensor / observer) OR alternative use to endoscopy	**B1**
	extra detail, e.g. laser light source, illuminated organ, image, camera / type of sensor	**B1**
(c)	any mention of frequency	**B1**
	(all of light) same / single / one frequency	**B1**

Q38.

Question	Answer	Marks
(a)	(point) where incident parallel rays meet after passing through lens OR origin of rays that emerge parallel after passing through lens	**M1**
	on principal axis OR use of term paraxial OR centre line	**A1**
(b)(i)	**enlarged virtual upright** two correct answers underlined AND no more than one wrong answer underlined	**M1**
	three correct answers underlined AND no wrong answer underlined	**A1**
(b)(ii)1	both principal focuses marked at points 5.0 cm from the optical centre	**B1**
(b)(ii)2	any **two** construction lines from: • line from top of I towards far principal focus and traced back from lens horizontally • line from top of I to (and through) centre of lens • horizontal line from top of I to lens and traced back to near principal focus	**B2**
	O marked with top at intersection	**B1**
(b)(iii)	2.7 cm ⩾ distance ⩾ 3.1 cm	**B1**

Q39.

Question	Answer	Marks
(a)	incident ray travels straight on at first face of prism 1	**B1**
	ray reflected through 90° at sloping face of prism 1 continues vertically downwards to sloping face of prism 2	**B1**
	ray reflected through 90° at sloping face and leaves box horizontally	**B1**
(b)	n = 1 / sin C in any form OR (n =) 1 / sin C	**B1**
	{(n=) 1 / sin 45 OR (n=) 1 / 0.707} AND (n=) 1.41	**B1**

Q40.

Question	Answer	Marks
(a)(i)	Refraction **OR** reflection	**1**
(a)(ii)	If refraction in **(i)** Change or increase or decrease in speed of wave **OR** change of refractive index **OR**	**1**
	If reflection in **(i)** Mention of surface or boundary	**(1)**
(b)(i)	2 points both labelled F at 3.5 cm either side of optical centre of lens	**1**
(b)(ii)	Any **two** of: Paraxial ray from tip of O refracted through farther F/3.5 cm Undeviated ray from tip of O through optical centre of lens Ray from tip of O through nearer F refracted paraxially	**2**
	Image/I drawn from intersection of rays to principal axis with indication that image is inverted	**1**
(b)(iii)	In range 3.6 to 4.1 cm	**1**
(b)(iv)	(Image is) real **and** light passes through it **OR** can be projected/seen on a screen **OR** refracted rays cross/meet	**1**