01. 0625_m23_ms_42 Q: 5

Question	Answer	Marks
(a)(i)	42°	**A2**
	n = 1 / sin c **OR** c = $\sin^{-1}$ (1 / n) **OR** c = $\sin^{-1}$ (1 / 1.5)	(C1)
(a)(ii)	ray continues along radius of semicircle within plastic	**M1**
	ray reflected inside plastic on straight edge, with angle of reflection = angle of incidence AND emerges from block along the normal	**A1**
(b)(i)	(focal length =) 7.2 cm	**B1**
(b)(ii)	**two** correct rays from: • ray from top of object through centre of lens • ray from top of object (that would pass through F on LHS of lens) refracted parallel to the principal axis • ray from top of object to lens, parallel to principal axis, refracted through F (same distance on right of lens as F marked on left of lens)	**M2**
	Two rays correctly extended back to intersect to left of object and line from principal axis to top of image labelled I.	**A1**
(c)	diverging lens in front of eye lens	**B1**
	rays meeting on the retina	**B1**

02. 0625_s23_ms_41 Q: 5

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**

03. 0625_s23_ms_42 Q: 7

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

04. 0625_s23_ms_43 Q: 4

Question	Answer	Marks
(a)(i)	two correct rays extended back (towards the intersection)	**M1**
	extended rays intersect	**A1**
	image drawn from intersection to principal axis **AND** base of image lies in correct range	**B1**
(a)(ii)	circles around: • enlarged • virtual • upright	**B3**
(b)(i)	long-sightedness / long sight / far-sighted	**B1**
(b)(ii)	converging lens reduces focal length of eye **OR** converging lens brings focal point forward **OR** without lens, rays converge behind back of eye	**B1**
	(so that) rays converge / focus on back of eye / retina	**B1**

05. 0625_w23_ms_41 Q: 6

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**

06. 0625_w23_ms_42 Q: 5

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**

07. 0625_m22_ms_42 Q: 5

Question	Answer	Marks
(a)(i)	straight line from clock to mirror AND from mirror to eye with correct arrows	**B1**
	Angle of incidence = angle of reflection	**B1**
(a)(ii)	Correct position of image	**B1**
(a)(iii)	Virtual (no mark) And Cannot be projected on a screen / light doesn't pass through image / AW	**B1**

Question	Answer	Marks
(a)(iv)		B1
(b)(i)	(monochromatic light) is light of a single frequency	B1
(b)(ii)	5.4×10^{14} Hz	A3
	(speed of light =) 3×10^{8} (m / s)	(C1)
	(f =) v / λ in any form OR $3.0 \times 10^{8} / 5.6 \times 10^{-7}$	(C1)

08. 0625_s22_ms_41 Q: 7

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

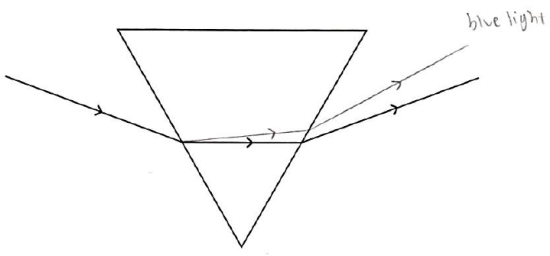
09. 0625_s22_ms_42 Q: 6

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

10. 0625_w22_ms_41 Q: 6

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

11. 0625_w22_ms_42 Q: 6

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 closer 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

12. 0625_w22_ms_43 Q: 7

Question	Answer	Marks
(a)	any **two** from: • all light is reflected • no light is refracted • (occurs) when light travels in a more dense medium towards a (boundary with a) less dense medium	**B2**
(b)(i)	(x =) 48°	**A3**
	n = 1 / sin c **OR** c = $\sin^{-1}$ (1 / n) **OR** sin c = 1 / 1.5 **OR** c = $\sin^{-1}$ (1 / 1.5)	C1
	c = 42(°)	C1
(b)(ii)	(speed =) 2.0×10^8 m / s	**A2**
	$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in liquid}}$ **OR** $n = \frac{\text{(approx.) speed of light in air}}{\text{speed of light in liquid}}$ **OR** n = c / v **OR** (v =) c / n **OR** $1.5 = \frac{3\times10^8}{\text{speed of light in liquid}}$	C1

13. 0625_m21_ms_42 Q: 6

	Answer	Marks
(a)	Any two correct rays from • from O through optical centre (and beyond) • from O parallel to principal axis to centre line of lens then through F_1 • from F_2 through O to centreline of lens then parallel to principal axis	**M2**
	rays traced back to intersect **AND** 2.4 – 3.6 cm	**A1**
(b)	magnified	**B1**
	same way up as object	**B1**
	virtual	**B1**
(c)	one ray from each prism refracted towards principal axis	**B1**
	(rays) converge to the right of original convergence on the principal axis	**B1**

14. 0625_s21_ms_42 Q: 6

	Answer	Mark
(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 = fλ 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**

15. 0625_s21_ms_43 Q: 6

	Answer	Mark
(a)	principal focuses marked in correct position	B1
(b)	1 mark for each of: • 1 correct ray • 2nd correct ray • 3rd correct ray and image, labelled I, in correct position with arrow at bottom	B3
(c)	real	B1
	inverted and enlarged	B1
(d)(i)	(image produced by a magnifying glass is) upright OR NOT inverted OR virtual	B1
(d)(ii)	position marked between principal focus and lens	B1

16. 0625_w21_ms_41 Q: 5

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

17. 0625_w21_ms_42 Q: 7

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

18. 0625_w21_ms_43 Q: 7

Question	Answer	Marks
(a)(i)		**B2**
	ray approaching left hand face of prism closer to normal than emerging ray	B1
	ray entering right hand face of prism showing refraction towards normal for ray already drawn	B1
(a)(ii)	light of single frequency	**B1**
(b)(i)	$3(.0) \times 10^8$ m / s	**B1**
(b)(ii)	5.8×10^{14} Hz	**A2**
	(f =) v / λ in any form OR $3.0 \times 10^8 / 5.2 \times 10^{-7}$	C1
(b)(iii)	2.0×10^8 m / s	**A2**
	refractive index = speed of light in air / speed of light in glass in any form	C1

19. 0625_m20_ms_42 Q: 7

(a)(i)	one correct ray	**B1**
	second correct ray	**B1**
	rays intersect above axis to left of A AND object drawn from axis to intersection	**B1**
(a)(ii)	AC	**B1**
	CB	**B1**
(b)(i)	ray in prism refracted down less than green ray	**B1**
(b)(ii)	ray in rectangular block refracted down less than green ray	**B1**
(b)(iii)	ray leaving rectangular block parallel to incident ray	**B1**

20. 0625_s20_ms_41 Q: 5

(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**

21. 0625_s20_ms_42 Q: 6

(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**

22. 0625_s20_ms_43 Q: 7

(a)	sin *i* / sin *r* = n in any form	**C1**
	r = 18°	**A1**
(b)	light travelling from optically dense medium to optically less dense medium	**B1**
	all light reflected OR no light refracted	**B1**
	angle of incidence is greater than the critical angle	**B1**
(c)	ray reflected at face AB with *i* = *r* by eye	**B1**
	ray refracted at face BC and bent away from the normal	**B1**

23. 0625_w20_ms_41 Q: 6

Question	Answer	Marks
(a)	speed changes **or** (wave) speed is smaller in right-hand part of tank **or** waves slow down **or** bottom (on the page) section of wave hits the boundary first	**C1**
	(wave) speed is smaller in right-hand part of tank **or** waves slow down **or** bottom (on the page) section of wave hits the boundary first	**C1**
	bottom (on the page) / one part / one side / one section of wave slows down first (and different sections are delayed by different amounts)	**A1**
(b)(i)	(*f* =) $v \div \lambda$ (in any form) **or** 0.39 ÷ 0.052 **or** 0.39 ÷ 0.026 **or** 15 (Hz) **or** 0.39 ÷ 5.2 **or** 0.39 ÷ 2.6 **or** 0.15 (Hz) **or** 0.075 (Hz)	**C1**
	0.39 ÷ 0.052 **or** 15 (Hz) **or** 0.39 ÷ 5.2 **or** 0.15 (Hz) **or** 0.075 (Hz)	**C1**
	7.5 Hz	**A1**
(b)(ii)	angle of incidence / *i* = 45(°) **or** angle of refraction / *r* = 33(°)	**C1**
	(v_2 =) $v_1 \times \sin(r) \div \sin(i)$ (in any form) **or** $\lambda_2 = \lambda_1 \times \sin(r) \div \sin(i)$ (in any form) **or** 0.39 × sin(33°) ÷ sin(45°) **or** 0.39 × sin(57°) ÷ sin(45°)	**C1**
	0.30 m / s	**A1**

24. 0625_w20_ms_41 Q: 9

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**

25. 0625_w20_ms_42 Q: 7

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**

26. 0625_m19_ms_42 Q: 8

(a)(i)	Wavefronts in the air: Parallel to each other	**B1**
	Make a larger angle with the boundary than wavefronts in ice and from top left to bottom right	**B1**
	At least one wavefront meets a wavefront in ice at the boundary	**B1**
(a)(ii)	Arrows at right angles to wavefronts pointing away from boundary	**B1**
(a)(iii)	Acute angle between any wavefront in ice and boundary marked *i* Acute angle between any wavefront in air and boundary marked *r*	**B1**
	OR In ice, normal at boundary and ray perpendicular to any wavefront both drawn. Angle between normal and ray in ice marked *i*. In air, normal at boundary and ray perpendicular to any wavefront both drawn. Angle between normal and ray in air marked *r*.	**(B1)**

(b)	n = speed in air / speed in ice OR n = V_{AIR} / V_{ICE} OR (V_{ICE})= V_{AIR} / n OR $3.0 \times 10^8 / 1.3$	**C1**
	2.3×10^8 m/s	**A1**

27. 0625_s19_ms_41 Q: 6

(a)	idea of one side of wavefront enters / hits solid first **OR** wavefront does not all hit the solid all at once;	**B1**
	idea of this side slowed down first **OR** this side delayed relative to other side	**B1**
	angle of wave(front) changes **OR** different parts of wavefront delayed by different amounts	**B1**
(b)(i)	$n = \frac{\sin i}{\sin r}$ in any form **OR** $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **OR** $1.3 = \frac{\sin 67°}{\sin r}$ **OR** (r =) $\sin^{-1}(\sin 67° / 1.3)$ **OR** $\sin^{-1}(0.71)$	**C1**
	45°	**A1**
(b)(ii)	$v_{ts} = c / n$ in any form **OR** (v_{ts} =) c / n **OR** $3.0 \times 10^8 / 1.3$	**C1**
	2.3×10^8 **OR** $3.0 \times 10^8 / 1.3$	**C1**
	$\lambda = v / f$ in any form **OR** (λ =) v / f **OR** $2.3 \times 10^8 / 5.7 \times 10^{14}$ **OR** $3.0 \times 10^8 / (1.3 \times 5.7 \times 10^{14})$	**C1**
	4.0×10^{-7} m	**A1**
	OR (alternative approach)	
	$\lambda = v / f$ in any form **OR** (λ =) v / f **OR** $3.0 \times 10^8 / 5.7 \times 10^{14}$	**C1**
	5.3×10^{-7} **OR** $3.0 \times 10^8 / 5.7 \times 10^{14}$	**C1**
	$\lambda_g = \lambda_a / n$ in any form **OR** (λ_g =) λ_a / n **OR** $5.3 \times 10^{-7} / 1.3$ **OR** $3.0 \times 10^8 / (1.3 \times 5.7 \times 10^{14})$	**C1**
	4.0×10^{-7} m	**A1**

28. 0625_s19_ms_42 Q: 7

(a)	both rays straight to left of lens AND top ray bends clockwise AND bottom ray bends anti-clockwise	**B1**
	both rays converge to meet on the centreline at the screen	**B1**
(b)	both rays straight to left of lens AND top ray bends clockwise less than in **(a)** AND bottom ray bends anti-clockwise less than in **(a)**	**B1**
	both rays converge and/would meet beyond screen	**B1**
(c)(i)	object closer to lens than one focal length	**B1**
(c)(ii)	(image) same side (of lens as object) OR image further from lens (than object)	**B1**

(c)(iii)	1 from 3 of : (image) enlarged/magnified, upright / goes up, virtual	**B1**
	all 3: (image) enlarged, upright, virtual	**B1**

29. 0625_s19_ms_43 Q: 7

(a)	40°	**B1**
(b)	n = 1.3 OR seen in calculation	**C1**
	$\sin i / \sin r = n$ in any form OR $\sin 40 / \sin r = n$ $\sin i / \sin r = 1 / n$	**C1**
	($\sin r = 1.3 \times \sin 40°$) (r =) 57°	**A1**

30. 0625_w19_ms_41 Q: 8

(a)(i)	n = sin(i) / sin(r) in any form words, symbols or numbers **or** (n =) sin(i) / sin(r) **or** sin(53°) / sin(30°) 1.6	**C1** **A1**
(a)(ii)	path emerging into air along correct path (by eye) **and** labelled R	**B1**
(a)(iii)	ratio / division of two identical quantities / speeds / sine functions / (pure) numbers	**B1**
(b)(i)	path labelled V with two correct refractions **and** below path of red light in glass	**B1**
(b)(ii)	larger frequency results in smaller speed (in glass) **or** r.a. (reverse argument) **or** inversely related / proportional. any **two** from: more refraction / closer to normal / larger refractive index for larger frequency **or** r.a. violet light has larger frequency **or** o.r.a. violet light has a smaller speed (in glass) **or** o.r.a. violet light has larger refractive index **or** o.r.a.	**B1** **B2**

31. 0625_w19_ms_42 Q: 6

(a)(i)	{light from water OR light to air / eye OR light from coin} bends / changes direction / is refracted	**B1**
	refracts / bends away from normal OR angle of incidence is smaller than angle of refraction	**B1**
(a)(ii)	refraction	**B1**
(a)(iii)	rays do not meet at image / only appear to come from image / do not originate from image / cannot be seen on a screen owtte	**C1**
(b)	3.0×10^8 m / s	**B1**
(c)	n = c_a / c_w in any form OR (c_w =) c_a / n	**C1**
	(c_w =) candidate's **(b)** / 1.3	**C1**
	(c_w =) 2.3×10^8 m / s	**A1**

32. 0625_w19_ms_43 Q: 7

(a)	ray parallel to axis and through F	**M1**
	ray through centre of lens	**M1**
	position of image correct and labelled	**A1**
(b)	enlarged and upright	**B1**
	virtual	**B1**
(c)	different colours have different wavelengths / different frequencies / refracted by different amounts OR dispersion (in glass)	**B1**

33. 0625_m18_ms_42 Q: 7

(a)	n = speed in air / speed in water OR speed in water = 3.0×10^8 / 1.33	**C1**
	2.3×10^8 m / s	**A1**
Answers to **(b)(i)**, **(b)(ii)** and **(b)(iii)** all combined to maximum of 5 marks on same screen		
(b)(i)	Wavefronts in plastic: meet wavefronts in air	**B1**
	make smaller angle with boundary than wavefronts in air and downwards to the left	**B1**
	parallel to each other	**B1**
(b)(ii)	Arrow(s) perpendicular to wavefronts in plastic and downwards to right	**B1**
(b)(iii)	*r* in plastic between refracted wavefront and boundary	**B1**
	OR At a point where refracted wavefront meets boundary, normal to boundary drawn and line perpendicular to wavefront drawn. *r* in plastic between the two lines drawn	**(B1)**

34. 0625_s18_ms_41 Q: 5

(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**

35. 0625_s18_ms_42 Q: 7

(a)	(speed/it) decreases	**1**
	refractive index > 1.0 **OR** sin (*i*) > sin (*r*) **OR** *i* > *r* **OR** refraction/bends towards normal **OR** $n_p > n_w$ **OR** sin (*i*) ÷ sin (*r*) = $c_w \div c_p$	**1**
(b)(i)	paraxial ray refracts through F_2	**1**
	other ray continues undeviated	**1**
(b)(ii)	candidate's rays from **(b)(i)** traced back to intersection	**1**
	image marked from intersection of candidate's rays to axis	**1**
(b)(iii)	in range 2.7 cm to 3.3 cm **AND** rays converge to the left of the object	**1**
(b)(iv)	virtual **AND** light does not pass through image/cannot be projected on to a screen **OR** object distance < f **OR** on left of object	**1**

36. 0625_s18_ms_43 Q: 7

(a)	one side of wave(front) slows down before the other side	**B1**
	wave(front) slews around **OR** bends at boundary	**B1**
	bends towards the normal **OR** bends towards the side that slows first	**B1**
(b)	($n =$) $c \div v$ **OR** $(3.0 \times 0^8) \div (1.9 \times 10^8)$	**C1**
	1.6	**A1**

37. 0625_s18_ms_43 Q: 8

(a)(i)	straight line from tip of O to tip of I	**B1**
	dotted line/lens marked at 3.0 cm from O	**B1**
(a)(ii)	Any **one** of: paraxial ray from tip of O refracting at lens to tip of I paraxial ray to I from lens **and** ray from O to meet it at lens	**B1**
(a)(iii)	(focal length) in range 2.2 cm to 2.6 cm	**B1**
(a)(iv)	real **and** light pass through it/projected on to screen/rays converge	**B1**
(b)	(focused rays) set fire to curtain	**B1**

38. 0625_w18_ms_41 Q: 7

(a)	Light of a single colour / wavelength / frequency	**B1**
(b)(i)	Reflected wavefronts:	
	In air, at least 3 wavefronts parallel to each other.	**B1**
	Same spacing as incident wavefronts	**B1**
	Reflecting at same angle with surface as incident wavefronts	**B1**
(b)(ii)	Refracted wavefronts:	
	In glass, at least 3 wavefronts parallel to each other AND continuous with incident wavefronts, unless drawn to right of incident wavefronts.	**B1**
	Smaller wavelength than incident wavefronts AND equally spaced.	**B1**
	At smaller angle with surface than incident wavefronts and rotated clockwise compared to incident wavefronts	**B1**
(c)	Rope drawn with **two** of: Amplitude labelled Wavelength labelled Crest and trough labelled	**B2**

39. 0625_w18_ms_42 Q: 5

(a)(i)	dispersion	**B1**
(a)(ii)	point A: red point B: violet	**B1**
(a)(iii)	different speeds / refractive indices / refractions(for different colours / wavelengths)	**B1**
(b)(i)	1 more reflection on top wall of fibre, between X and end of fibre AND 0 reflections on lower wall of fibre AND ray reaches end of fibre	**B1**
(b)(ii)	$\sin c = 1 / n$ in any form	**C1**
	($c = \sin^{-1}(1 / 1.46)$ =) 43°	**A1**
(b)(iii)	Any **two** from • to carry (telephone) signals / communications • for medical diagnosis / imaging • specified artistic (display) • specified lighting	**B2**

40. 0625_w18_ms_43 Q: 6

(a)(i)	correct refractions **and** dispersion at first surface	**M1**
	correct **and** more refractions of both rays at second surface **and** (more) divergence **and** labels	**A1**
(a)(ii)	violet	**B1**
(b)(i)	(light of) a single frequency	**B1**
(b)(ii)	total internal reflection (at side AC) **or** internal reflection **and** no refraction	**B1**
	angle of incidence greater than critical angle / 42° (and refractive index of glass greater than that of air than air)	**B1**
(b)(iii)	light refracts (at Y)	**B1**
	angle of incidence less than critical angle / 42°	**B1**
	(some) light reflects	**B1**

41. 0625_m17_ms_42 Q: 7

(a)	Diminished, inverted and real ticked. All correct = 2 marks; 1 or 2 correct = 1 mark; contradiction loses 1 mark.	**B2**
(b)	Incident ray parallel to axis from tip of object to centre line of lens. Refracted ray from centre line of lens to tip of image OR: Refracted ray parallel to axis from tip of image to centre line of lens. Incident ray from tip of object to meet refracted ray at centre line of lens Principal focus to right or left of lens marked	**B1**
(c)	Candidate's distance from centre of lens to point marked F (even if clearly in wrong position) OR candidate's distance from centre of lens to correct point even if not marked F	**B1**
(d)	Any straight-line ray from tip of object to tip of image, not passing through a principal focus of the lens, that changes direction at centre line of lens	**B1**
	Total:	**5**

42. 0625_s17_ms_41 Q: 6

(a)(i)	(Ray passes into the air and) refracts / changes direction / bends	**B1**
(a)(ii)	Total internal reflection (takes place)	**B1**
(b)(i)	Total internal reflection at B with angle of incidence equal to angle of reflection (by eye)	**B1**
	Refraction into air at right-hand face with angle of refraction greater than angle of incidence	**B1**
(b)(ii)	(n =) 1/sin c OR 1/sin 41	**M1**
	1.5	**A1**
	Total:	**6**

43. 0625_s17_ms_42 Q: 7

(a)(i)	(n =) speed in air / speed in liquid	**C1**
	(n = 3×10^8 / 2.0×10^8) = 1.5	**A1**
(a)(ii)	n = sin i / sin r in any form	**C1**
	(r = $\sin^{-1}$ (sin 40 / 1.5) =) 25°	**A1**
(b)	one ray from object either with refraction at surface OR vertical	**M1**
	another ray from object, must have refraction at surface away from normal	**A1**
	both rays extended back to meet in the liquid AND intersection labelled image/ I	**B1**
	Total:	**7**

44. 0625_s17_ms_43 Q: 8

(a)	OP/it is along the normal/at 90° (to the curved surface)	**B1**
(b)(i)	sin *i* / sin *r* = *n*	**C1**
	sin *r* / sin 30(°) = 1.5 OR sin *r* = 1.5 × sin 30(°)	**C1**
	49°	**A1**
(b)(ii)	ray bends away from the normal **c.a.o.**	**B1**
(c)	angle (from normal) of refraction increases	**B1**
	refracted ray travels along boundary OR reflected ray becomes brighter OR refracted ray becomes dimmer	**B1**
	light reflects back into glass (with *i* = *r*)	**B1**
	Total:	**8**

45. 0625_w17_ms_41 Q: 7

(a)	One ray with correct path through lens	**B1**
	Another ray with correct path through lens Rays intersect to right of F and below axis, inverted image	**B1**
	drawn and labelled I	**B1**
(b)	enlarged, upright and virtual only underlined or ringed	**B2**
	Two of above descriptions underlined	**B1**
(c)	On entering prism: green ray deflection more than red ray and above normal	**B1**
	On leaving prism: diverging downwards from red ray and not along surface of prism	**B1**

46. 0625_w17_ms_42 Q: 7

(a)	real (answers in any order for **7(a)**)	**B1**
	enlarged OR magnified	**B1**
	Inverted OR upside down	**B1**
(b)(i)	1st straight incident ray from close to point object to mirror correctly reflected, $i = r$	**M1**
	2nd straight incident ray from point object to mirror correctly reflected, $i = r$	**A1**
(b)(ii)	BOTH reflected rays extended back to intersect behind mirror	**M1**
	BOTH reflected rays extended back in straight lines AND I in correct position AND {labelled OR clearly indicated}	**A1**

47. 0625_w17_ms_43 Q: 7

(a)(i)	any **two** rays that start at the top of the image from: • seems to come from F_1 to lens and emerges paraxially • passes through centre of lens undeviated • paraxial to the lens and passes through F_2	**M2**
	two correct rays traced back **and** image indicated	**A1**
(a)(ii)	any **two** of enlarged; inverted; real underlined	**B1**
	enlarged **and** inverted **and** real underlined	**B1**
(b)	refracted ray in prism below yellow ray **and** above normal	**B1**
	emergent ray diverging away from the yellow ray and above side of prism	**B1**