1 **(a** (n =) sin i / sin r **OR** sin 62 / sin 36 C1
1.5(02) C1
(v_g =) c / n **OR** 3.0×10^8 / 1.5 C1
2.0 / 2.00 / 1.997 $\times 10^8$ m / s A

(b) (infra-red / light) encoded **OR** (sent as) pulses **OR** multiplexing **OR** many messages **OR** signal **OR** information **OR** data **OR** internet B1
(optical fibre transmits) light / infra-red (pulse) B1
total internal reflection / TIR (prevents escape) B1

[Total: 7]

2 **(a** two of:
ray <u>through</u> centre of lens undeviated
ray parallel to axis refracted to right hand focus B2
rays through left hand focus refracted parallel to axis

rays extrapolated to a point B1

accuracy marks: image 6 cm from lens B1
image 6 cm high B1

(b) image is virtual/not real <u>AND</u>
cannot be seen on screen OR no rays come from (position of) image B1

[Total 6]

3 **(a** correct reflection of left ray
AND 22° ≤ angle between right ray and surface ≤ 32°, by protractor B1
rays projected back to form image in correct position B1 [2]

(b) both rays refract down M1
rays projected back to form image somewhere in water to the left of where left ray strikes surface A1 [2]

(c) $\sin c = 1 / 1.33$ OR $\sin c / \sin r = 1 / 1.33$ C1
OR $\sin^{-1}(1 / 1.33)$ OR $\sin^{-1} 0.75$
($c = 48.8°$ =) 49° A1 [2]

(d) appropriate use, accept diagram
accept 'endoscope', 'in medicine' is not sufficient M1
clear diagram of the above use or t.i.r. diagram for optical fibre A1
one from:
light goes down fibre/into body
illuminates internal organ
light/image returns from body/organ o.w.t.t.e. A1 [3]

[Total: 9]

4 **(a (i)** (only) one frequency (accept wavelength) B1

(ii) 4.7×10^{14} Hz OR the same as before OR unchanged B1

(b) (n =)c/v OR $3.0 \times 10^8 / 2.0 \times 10^8$ M1
1.5 A1

(ii) (λ =)c/f OR $2.0 \times 10^8 / 4.7 \times 10^{14}$ C1
$4.3/4.26/4.255319 \times 10^{-7}$ m A [6]

5	**(a**	**(i)**	BOX 2 ticked virtual BOX 3 ticked magnified		B1 B1	
		(ii)	AB circled		B1	[3]
	(b)		normal at M towards C		B1	[1]
		(ii)	40° ≤ angle of reflection ≤ 50°		B1	[1]
		(iii)	any clear indication that OP is also the reflected ray		B1	[1]
		(iv)	lines extended back from M and P to meet to the right of mirror AND indication of intersection as image position		M1	
			image within 25 mm of right hand margin line AND higher than P but within 16 mm			[2]
					[Total: 8]	
6	**(a**		n = sin i/sin r **or** n = sin r/sin i **or** (sin i =) 1.5 sin 40(°) i **or** (sin r =) 1.5 sin 40(°) **or** 25° 0.9641 75/74.6 ° to 2 or more sig. figs.		C1 C1 A1	[3]
	(b)	**(i)**	(v =) $f\lambda$ **or** $3.8 \times 10^{14} \times 5.3 \times 10^{7}$ 2.01×10^{8} m / s to 2 or more sig. figs.		C1 A1	[2]
		(ii)	(c =) nv **or** $1.5 \times 2.0/2.01/2.014 \times 10^{8}$ (e.c.f. from **7(b)(i)**) 3.02×10^{8} m / s (accept 3 or 3.0×10^{8} m / s only with working) (e.c.f. from **7(b)(i)**)		C1 A1	[2]
	(c)		wave(front) hits/enters the plastic at the same time **or** incident ray perpendicular along normal/at 90° **or** i = 0° (condone it doesn't hit at an angle) wave(front) all slows down at the same time **or** refracted ray perpendicular normal/at 90° **or** r = 0° by calculation		B1 B1	[2]
					[Total: 9]	