1 **(a) (i)** $2.0 – 4.0 \times 10^8$ m/s *Unit penalty applies B1

(ii) (f =) v/λ **or** $3.0 \times 10^8/4.0 \times 10^7$ ecf from **6(a)(i)** C1
7.5×10^{14} Hz *Unit penalty applies ecf from **6(a)(i)** A1

(b) (i) 55° *Unit penalty applies B1

(ii) sin i/sin r = n **or** sin 55°/1.5 **or** 0.54610 ecf from **6(b)(i)** C1
33° *Unit penalty applies ecf from **6(b)(i)** A1 **[6]**

***Apply unit penalty once onl

2 **(a)** idea of fine ray/beam shone into (glass) block / pins appropriately placed shown in diagram or described B1
angles *i* & *r* or *C* measured OR correct *i* & *r* or *C* marked on diagram B1
sin*i*/sin*r* OR sin*r*/sin*i* OR 1/sin*C* OR sin*C* B1
n = speed in air/speed in glass OR *c*/*v* = sin*i*/sin*r* OR *n* = 1/sin*C* OR *c*/*v* = 1/sin*C* B1

(b) (i) $v = f\lambda$ OR $240/1.9 \times 10^5$ OR $T=d/s$ AND $f=1/T$ B1
0.00126 Hz OR 0.0013 Hz NOT 0.0012 Hz
ignore more than 3 s.f. accept s^{-1} A1

(ii) distance = speed × time in any form accept $s = 2d/t$ C1
(time for tremor =) 240 (s) or 4 mins also gives first C1 C1
(time for tsunami =) 2500 (s) or 41 mins 40 s also gives first C1 C1
(warning time =) 2260 (s) or 37 mins 40 s A1 [10]

3 **(a** idea of light travelling (much) faster than sound B1

(b) (i) 4.0 (min) B1

(ii) always a (measurable) time difference / never zero time difference
Ignore time would be less B1

(iii) distance/time in any form, symbols, words, numbers OR 1200/3.6 C1
333.3 m/s to 2 or more sig figs A1

(iv) idea of light travelling instantaneously OR no wind
OR idea of lightning at ground level OR no obstruction to sound
Ignore echoes B1

(c)

	light waves	sound waves
longitudinal		✓
transverse	✓	
electromagnetic	✓	
mechanical		✓

–1 e.e.o.o. i.e. 1 mark subtracted from 3 for each error or omission B3 [9]

4 **(a) (i)** R in correct position, by eye B1

(ii) 3 reflected waves correctly meeting mirror)
3 reflected wave equidistant, by eye) -1 e.e.o.o B2
3 reflected waves centred on candidate's R)

(b) 1st ray + reflection correct by eye B1
2nd ray + reflection correct by eye B1
reflected rays projected back, to meet behind mirror
OR labelled I **and** in correct position B1

[Total: 6]

5	**(a)**		expect two internal reflections at sensible angles	**1**	**1**	
	(b)		angle of incidence at Y greater than critical angle	**1**		
			total internal reflection occurs	**1**	**2**	
	(c)	**(i)**	frequency = velocity/wavelength or $1.9 \times 10^{8} / 3.2 \times 10^{7}$	**1**		
			$= 5.9 \times 10^{14}$ Hz	**1**		
		(ii)	refractive index = 3/1.9 or 1.9/3	**1**		
			= 1.58 (no e.c.f.)	**1**	**4**	
					(7)	

6	**(a)**	**(i)**	incident ray, refracted ray and normal drawn	**C1**		
			all correct and meeting at a point	**A1**		
		(ii)	angle of incidence and refraction correctly identified	**B1**		
		(iii)	values correct within agreed limits	**B1**		**4**
	(b)		use of sini/sinr	**C1**		
			correct substitution from candidates values	**C1**		
			value correct within agreed limits from candidate's values	**A1**		**3**
						[7]

7	**(a)**		value 3 x 10 m/s	**A1**		**1**
	(b)		speed of light (much) greater than speed of sound or value for sound	**A1**		**1**
	(c)	**(i)**	source and receiver arrangement	**C1**		
			with detail and labels	**A1**		
		(ii)	distance between source and receiver	**B1**		
			time between flash and bang	**B1**		
		(iii)	speed = distance/time	**B1**		**max 4**
						[6]

8	**(a)**	two dots, marked F, each 5.0 cm from the lens	**A2**
	(b)	each correct ray one mark	**M2**
	(c)	correct image, labeled I	**A1**
	(d)	rays pass along the axis undeviated/object distance same for all object/rays meet at same distance on image/image distance same for all image	**B1**
	(e)	magnifying glass/eyepiece of telescope or microscope	**B1**

[7]

9 a(i) $43^{\circ} \pm 1^{\circ}$ 1 A1

(ii) angle r for this ray is 90° B1

angle c is angle i (in denser medium) ~~(giving angle r = 90°)~~ 2 B1 3

b(i) 3×10^{8} m/s* 1 A1

(ii) speed in air/speed in medium M1

= 1.5 (no up for °) 2 A1

(iii) angle i = 0° / along normal / at 90° to surface 1 B1

(iv) increased/more/larger 1 B1 5

QT 8