Q1.

4 (a) e.g. both transverse/longitudinal/same type
meet at a point,
same direction of polarisation, etc.......1 *each, max 3* .... B3 [3]
(allow 1 mark for any condition for observable interference)

(b) (i)1 allow 0.3 mm → 3 mm.. B1

(i)2 $\lambda = ax/D$ (allow any subject) B1

(ii)1 separation increased.. B1
less bright B1

(ii)2 separation increased.. B1
less bright B1

(ii)3 separation unchanged.. B1
fringes brighter B1
further detail, i.e quantitive aspect in (ii)1 or (ii)2............................ B1 [7]
(in (b), do not allow e.c.f. from (b)(i)2)

Q2.

2 (a) (i) λ = 0.6 m — B1
(ii) frequency (= v/λ) = 330/0.60 — C1
= 550 Hz — A1 [3]
(use of c = 3 x 10^8 ms^{-1} scores no marks)

(b) amplitude shown as greater than *a* but less than 2*a* and constant — B1
correct phase — B1 [2]
(wave to be at least three half-periods, otherwise -1 overall)

Total [5]

Q3.

6 (a) When two (or more) waves meet *(not 'superpose' or 'interfere')* — B1
resultant <u>displacement</u> — M1
is the sum of individual (displacements) — A1 [3]

(b) (i) any correct line through points of intersection of crests — B1
(ii) any correct line through intersections of a crest and a trough — B1 [2]

(c) (i) $\lambda = ax/D$ OR $\lambda = a\sin\theta$ and $\theta = x/D$ — C1
$650 \times 10^{-9} = (a \times 0.70 \times 10^{-3})/1.2$ — C1
$a = 1.1 \times 10^{-3}$ m — A1 [3]
(ii) 1 no change — B1
2 brighter — B1
3 no change *(accept stay/remain dark)* — B1 [3]

Total [11]

Q4.

5	(a)	When a wave (front) is incident on an edge or an obstacle/slit/gap	M1	
		Wave 'bends' into the geometrical shadow/changes direction/spreads	A1	[2]
	(b) (i)	$d = 1/(750 \times 10^3)$	C1	
		$= 1.33 \times 10^{-6}$ m	A1	[2]
	(ii)	$1.33 \times 10^{-6} \times \sin 90° = n \times 590 \times 10^{-9}$	C1	
		n = 2 (must be an integer)	A1	[2]
	(iii)	formula assumes no path difference of light before entering grating or there is a path difference before the grating	B1	[1]
	(c)	e.g. lines further apart in second order lines fainter in second order (allow any sensible difference: 1 each, max 2)	B2	[2]
		(if differences stated but without reference to the orders, max 1 mark)		

Q5.

6	(a) (i)	correct shape drawn	B1	[1]
	(ii)	two nodes marked correctly	B1	[1]
	(b)	$\frac{1}{2}\lambda = 0.324$ m	C1	
		$v = f\lambda$	C1	
		$= 512 \times 2 \times 0.324$		
		$= 332$ m s^{-1}	A1	[3]
	(c)	$\frac{1}{4}\lambda = 16.2$ cm	C1	
		either antinode is 0.5 cm above top of tube *or* antinode is 16.2 cm above water surface	A1	[2]

Q6.

5	**(a)** **(i)** vibrations (in plane) normal to direction of energy propagation	B1	[1]
	(ii) vibrations in one direction (normal to direction of propagation)	B1	[1]
	(b) **(i)** at (displacement) antinodes / where there are no heaps, wave has maximum amplitude (of vibration)	B1	
	at (displacement) nodes/where there are heaps, amplitude of vibration is zero/minimum	B1	
	dust is pushed to / settles at (displacement) nodes	B1	[3]
	(ii) $2.5\lambda = 39$ cm	C1	
	$v = f\lambda$	C1	
	$v = 2.14 \times 10^3 \times 15.6 \times 10^{-2}$ $= 334$ m s^{-1} (*allow 330, not 340*)	A1	[3]
	(c) Stationary wave formed by interference / superposition / overlap of	B1	
	either wave travelling down tube and its reflection *or* two waves of same (type and) frequency travelling in opposite directions	B1	
	speed is the speed of the incident / reflected waves	B1	[3]

Q7.

5	**(a)** **(i)** frequency: number of oscillations per unit time	M1	
	of the source / of a point on the wave	A1	[2]
	(ii) speed: speed at which energy is transferred / speed of wavefront	B1	[1]
	(b) **(i)** does not transfer energy (along the wave)	B1	[1]
	(ii) position (along wave) where amplitude of vibration is a maximum	B1	[1]
	(iii) all three positions marked	B1	[1]
	(c) wavelength = 2 × 17.8 = 35.6 cm	C1	
	$v = f\lambda$	C1	
	$v = 125 \times 0.356$ $= 44.5$ m s^{-1}	C1	
	$44.5^2 = 4.00 / m$	C1	
	$m = 2.0 \times 10^{[illegible]}$ kg m^{-1}	A1	[5]

Q8.

5	**(a)** *either* phase difference is π rad / 180° *or* path difference (between waves from S_1 and S_2) is $\frac{1}{2}\lambda$ / $(n + \frac{1}{2})\lambda$.	B1	
	either same amplitude / intensity at M *or* ratio of amplitudes is 1.28 / ratio of intensities is 1.28^2	B1	[2]
	(b) path difference between waves from S_1 and S_2 = 28 cm	B1	
	wavelength changes from 33 cm to 8.25 cm	B1	
	minimum when λ = (56 cm,) 18.7 cm, 11.2 cm, (8.0 cm)	B1	
	so two minima	B1	[4]

Q9.

5 **(a)** constant phase difference .... B1 [1]

(b) allow wavelength estimate 750 nm → 550 nm C1
separation = $\lambda D / x$ C1
= $(650 \times 10^{-9} \times 2.4) / (0.86 \times 10^{-3})$
= 1.8 mm .... A1 [3]
(allow 2 marks from inappropriate estimate if answer is in range 10 cm → 0.1 mm)

(c) no longer complete destructive interference /
amplitudes no longer completely cancel M1
so dark fringes are lighter .... A1 [2]

Q10.

4 **(a)** when a wave (front) passes by/incident on an edge/slit M1
wave bends/spreads (into the geometrical shadow) .... A1 [2]

(b) $\tan\theta = \frac{38}{165}$
$\theta = 13°$ C1
$d \sin\theta = n\lambda$ C1
$d = 2.82 \times 10^{-6}$ C1
number = $(1/d =)\ 3.6 \times 10^{5}$ .... A1 [4]

(c) P remains in same position B1
X and Y rotate through 90° .... B1 [2]

(d) *either* screen not parallel to grating
or grating not normal to (incident) light .... B1 [1]

Q11.

4 **(a)** e.g. no energy transfer
amplitude varies along its length/nodes and antinodes
neighbouring points (in inter-nodal loop) vibrate in phase, etc.
(any two, 1 mark each to max 2 ....B2 [2]

(b) (i) λ = (330 × 10^2)/550 .... M1
λ = 60 cm .... A0 [1]

(ii) node labelled at piston B1
antinode labelled at open end of tube B1
additional node and antinode in correct positions along tube .... B1 [3]

(c) at lowest frequency, length = λ/4 .... C1
λ = 1.8 m
frequency = 330/1.8 .... C1
= 180 Hz .... A1 [3]

Q12.

5 (a) (i) 1 number of oscillations per unit time (not per second) B1 [1]
2 $n\lambda$ A1 [1]

(ii) v = distance / time = $n\lambda/t$ M1
$n/t = f$ hence $v = f\lambda$ A1
or f oscillations per unit time so $f\lambda$ is distance per unit time M1
distance per unit time is v so $v = f\lambda$ A1 [2]

(b) (i) 1.0 period is 3 × 2 = 6.0 ms C1
frequency = 1 / (6 × 10^{-3}) = 170 Hz A1 [2]

(ii) wave (with approx. same amplitude and) with correct phase difference B1 [1]

Q13.

7 (a) when waves overlap / meet, (resultant) displacement is the sum of the individual displacements B1 [1]

(b) (i) two (ball-type) dippers (M1)
connected to the same vibrating source /motor (A1)
or
one wave source described (M1)
with two slits (A1) [2]

(ii) lamp with viewing screen on opposite side of tank B1
means of freezing picture e.g. strobe B1 [2]

(c) (i) two correct lines labelled X B1 [1]

(ii) correct line labelled N B1 [1]

Q14.

6 (a) (i)	to produce coherent sources or constant phase difference		B1	[1]
(ii) 1.	360° / 2π rad	allow n × 360° or n × 2π (unit missing –1)	B1	[1]
2.	180° / π rad	allow (n × 360°) – 180° or (n × 2π) – π	B1	[1]
(iii) 1.	waves overlap / meet		B1	
	(resultant) displacement is sum of displacements of each wave		B1	[2]
2.	at P crest on trough (OWTTE)		B1	[1]

(b) $\lambda = ax / D$ — C1
$= 2 \times 2.3 \times 10^{-3} \times 0.25 \times 10^{-3} / 1.8$ — C1
= 639 nm — A1 [3]

Q15.

6 (a) (i)	amplitude = 7.6 mm	allow 7.5 mm	A1	[1]
(ii)	180° / π rad		A1	[1]
(iii)	$v = f \times \lambda$			
	= 15 × 0.8		C1	
	= 12 m s^{-1}		A1	[2]
(b)	correct sketch with peak moved to the right		B1	
	curve moved by the correct phase angle / time period of 0.25 *T*		B1	[2]
(c) (i)	zero (rad)		A1	[1]
(ii)	antinode maximum amplitude, node zero amplitude / displacement		A1	[1]
(iii)	3		A1	[1]
(iv)	horizontal line through central section of wave		B1	[1]

Q16.

6 (a) (i)	coherence: constant phase difference	M1	
	between (two) waves	A1	[2]
(ii)	path difference is *either* λ *or* $n\lambda$ *or* phase difference is 360° *or* $n \times 360°$ *or* $n2\pi$ rad	B1	[1]

(iii) path difference is *either* $\lambda/2$ *or* $(n + ½)\lambda$		
or phase difference is odd multiple of *either* 180° *or* π rad	B1	[1]
(iv) $w = \lambda D / a$	C1	
$= [630 \times 10^{-9} \times 1.5] / 0.45 \times 10^{-3}$	C1	
$= 2.1 \times 10^{-3}$ m	A1	[3]
(b) no change to dark fringes	B1	
no change to separation/fringe width	B1	
bright fringes are brighter/lighter/more intense	B1	[3]

Q17.

6 (a) two waves travelling (along the same line) in opposite directions overlap/meet	M1	
same frequency / wavelength	A1	
resultant displacement is the sum of displacements of each wave / produces nodes and antinodes	B1	[3]
(b) apparatus: source of sound + detector + reflection system	B1	
adjustment to apparatus to set up standing waves – how recognised	B1	
measurements made to obtain wavelength	B1	[3]
(c) (i) at least two nodes and two antinodes	A1	[1]
(ii) node to node = $\lambda / 2$ = 34 cm (allow 33 to 35 cm)	C1	
$c = f\lambda$	C1	
f = 340 / 0.68 = 500 (490 to 520) Hz	A1	[3]

Q18.

6 (a) (i) diffraction bending/spreading of light at edge/slit	B1	
this occurs at each slit	B1	[2]
(ii) constant phase difference between each of the waves	B1	[1]
(iii) (when the waves meet) the resultant displacement is the sum of the displacements of each wave	B1	[1]
(b) $d\sin\theta = n\lambda$		
$n = d / \lambda = 1 / 450 \times 10^3 \times 630 \times 10^{-9}$	C1	
$n = 3.52$	M1	
hence number of orders = 3	A1	[3]
(c) λ blue is less than λ red	M1	
more orders seen	A1	
each order is at a smaller angle than for the equivalent red	A1	[3]

Q19.

5	**(a)** waves overlap / meet / superpose	(B1)	
	coherence / constant phase difference (*not constant λ or frequency*)	(B1)	
	path difference = 0, λ, 2λ or phase difference = 0, 2π, 4π	(B1)	
	same direction of polarisation/unpolarised	(B1)	
		max. 3	[3]
	(b) $\lambda = v / f$	C1	
	$f = 12 \times 10^9$ Hz	C1	
	$\lambda = 3 \times 10^8 / 12 \times 10^9$ (*any subject*)	M1	
	= 0.025 m	A0	[3]
	(c) maximum at P	B1	
	several minima or maxima between O and P	B1	
	5 maxima / 6 minima between O and P		
	or 7 maxima / 6 minima including O and P	B1	[3]
	(d) slits made narrower	B1	
	slits put closer together	B1	[2]
	(*not just 'make slits smaller'*)		
	Allow tilting the slits M1 and explanation of axes of rotation A1		

Q20.

5	**(a) (i)** $v = f\lambda$	C1	
	$\lambda = 40 / 50 = 0.8(0)$ m	A1	[2]
	(ii) waves (travel along string and) reflect at Q / wall / fixed end	B1	
	incident and reflected waves interfere / superpose	B1	[2]
	(b) (i) nodes labelled at P, Q and the two points at zero displacement	B1	
	antinodes labelled at the three points of maximum displacement	B1	[2]
	(ii) (1.5λ for PQ hence PQ = 0.8 × 1.5) = 1.2 m	A1	[1]
	(iii) $T = 1 / f = 1/50 = 20$ ms	C1	
	5 ms is ¼ of cycle	A1	
	horizontal line through PQ drawn on Fig. 5.2	B1	[3]

Q21.

5 (a) when waves overlap / meet — B1
the resultant displacement is the sum of the individual displacements of the waves — B1 [2]

(b) (i) 1. phase difference = 180° / (n + ½) 360° (allow in rad) — B1 [1]

2. phase difference = 0 / 360° / (n360°) (allow in rad) — B1 [1]

(ii) $v = f\lambda$ — C1
λ = 320 / 400 = 0.80 m — A1 [2]

(iii) path difference = 7 – 5 = 2 (m)
= 2.5 λ — M1
hence minimum
or maximum if phase change at P is suggested — A1 [2]

Q22.

5 (a) displacement & direction of energy travel normal to one another ... B1 [1]

(b) (i) phase angle of 60° correct .. (need to see 1½ wavelengths) B1
lags behind T_1 .... B1 [2]

(ii) waves must be in same place (at same time) B1
resultant displacement = sum of individual displacements .... B1 [2]

(iii) 1. – ½A B1
2. ½A ...... (allow e.c.f.) B1
3. zero ..... (allow e.c.f.) .... B1 [3]

Q23.

4 (a) (i)1 amplitude = 0.4(0) mm A1

(i)2 wavelength = 7.5 x 10^{-2} m
(1 sig. fig. -1 unless already penalised).. A1

(i)3 period = 0.225 ms C1
frequency = 1/T = 4400 Hz.. A1

(i)4 v = fλ
= 4400 x 7.5 x 10^{-2} C1
= 330 m s^{-1} .... A1 [6]

(a) **(ii)** reasonable shape, same amplitude and wavelength doubled ...... B1 [1]

(b) **(i)** 1.7(2) μm A1

(ii) d sin2 = $n\lambda$ (double slit formula scores 0/2)
$1.72 \times 10^{-6} \times \sin 2 = 590 \times 10^{-9}$ C1
2 = 20.1° (allow 20°).. A1

(iii) ½L = 1.5 tan20.1 .... C1
L = 1.1 m.. A1 [5]

Q24.

2 **(a)** all same speed in a vacuum (allow medium)/all travel in a vacuum (1)

transverse/can be polarised (1)

undergo diffraction/interference/superposition (1)

can be reflected/refracted (1)

show properties of particles (1)

oscillating electric and magnetic fields (1)

transfer energy/progressive (1)

not affected by electric and magnetic fields (1)

(allow any three, 1 each) **B3** **[3]**

(b) 495 nm = 495×10^{-9} m **C1**

number = $1/(495 \times 10^{-9}) = 2.02 \times 10^{6}$ **A1** **[2]**

(allow 2 or more significant figures)

(c) **(i)** allow $10^{-7} \rightarrow 10^{-11}$ m **B1**

(ii) allow $10^{-3} \rightarrow 10^{-6}$ m **B1** **[2]**

Q25.

4	**(a)**	wavelength = 1.50 m	**B1**	**[1]**
	(b)	v = $f\lambda$	**C1**	
		speed = 540 m s^{-1}	**A1**	**[2]**
	(c)	(progressive) wave reflected at the (fixed) ends	**B1**	
		wave is formed by superposition of (two travelling) waves	**B1**	
		this quantity is the speed of the travelling wave	**B1**	**[3]**

Q26.

5	**(a)**		similarity: e.g. same wavelength/frequency/period, constant phase difference	B1	
			difference: e.g. different amplitude/phase (do not allow a reference to phase for both similarity and difference)	B1	**[2]**
	(b)		constant phase difference so coherent	B1	**[1]**
	(c)	**(i)**	*intensity* $\propto$ *amplitude*^{2}	C1	
			$I \propto 3^2$ and $I_B \propto 2^2$ leading to	M1	
			$I_B = \frac{4}{9}I$	A0	**[2]**
		(ii)	resultant amplitude = 1.0×10^{-4} cm	C1	
			resultant intensity = $\frac{1}{9}I$	A1	**[2]**
	(d)	**(i)**	displacement = 0	B1	**[1]**
		(ii)	$x_A = -2.6 \times 10^{-4}$ cm and $x_B = +1.7 \times 10^{-4}$ cm allow $\pm 0.5 \times 10^{-4}$ cm)	C1	
			resultant displacement = (-) 0.9×10^{-4} cm	A1	**[2]**

Q27.

4	**(a)**	**(i)**	when two (or more) waves meet (at a point)	M1	
			there is a change in overall intensity / displacement	A1	
		(ii)	constant phase difference (between waves)	B1	[3]
	(b)	**(i)**	$d\sin\theta = n\lambda$	B1	
			$(10^{-3} / 550)\sin 90 = n \times 644 \times 10^{-9}$	C1	
			$n = 2.8$	C1	
			so two orders	A1	[4]
			(power-of-ten error giving 2800 orders, allow 1/3 only for calculation of n)		
		(ii)	**1.** $d\sin\theta = n\lambda$ *(either here or in **(i)** – not both)*		
			θ is greater so λ is greater	B1	[1]
			2. when n is larger, $\Delta\theta$ is larger	M1	
			so greater in second order	A1	[2]

Q28.

5	(a)		amplitude between 6.5 squares and 7.5 squares on 3 peaks (*allow 1 mark if outside this range but between 6.0 and 8.0 squares*) correct phase (ignore lead/lag, look at x-axis only and allow ±½ square	B2 B1	[3]
	(b)		$\lambda = ax / D$ $540 \times 10^{-9} = (0.700 \times 10^{-3}\ x) / 2.75$ $x = 2.12$ mm	C1 C1 A1	[3]
	(c)	(i)	same separation bright areas brighter (1) dark areas, no change (1) (*allow 'contrast greater' for 1 mark if dark/light areas not discussed*) fewer fringes observed (1) *any two, 1 each*	B1 B2	[3]
		(ii)	smaller separation of fringes no change in brightness	B1 B1	[2]

Q29.

6	(a)		<u>wave</u> incident at an edge / aperture / slit /(edge of) obstacle bending / spreading of wave (into geometrical shadow) (*award 0/2 for bending at a boundary*)	M1 A1	[2]
	(b)	(i)	apparatus e.g. laser & slit / point source & slit / lamp and slit & slit microwave source & slit water / ripple tank, source & barrier detector e.g. screen aerial / microwave probe strobe / lamp what is observed	 B1 B1 B1	[3]
		(ii)	apparatus e.g. loudspeaker, and slit / edge detector e.g. microphone & c.r.o. / ear what is observed	B1 B1 B1	[3]

Q30.

5 **(a)** transfer / propagation of energy M1
as a result of oscillations / vibrations .... A1 [2]

(b) **(i)** displacement / velocity / acceleration (of particles in the wave) .... B1 [1]

(ii) displacement etc. is normal to direction of energy transfer /
travel of wave / propagation of wave ......(*not 'wave motion'*) .... B1 [1]

(iii) displacement etc. along / same direction of energy transfer /
travel of wave / propagation of wave ......(*not 'wave motion'*) .... B1 [1]

(c) diffraction: suitable object, means of observation M1
either laser *or* lamp and aperture
or distant source M1
light region where darkness expected A1

interference: suitable object, means of observation and illumination B1
light and dark fringes observed B1
appropriate reference to a dimension for diffraction or
for interference .... B1 [6]

[Total: 11]

Q31.

5 **(a)** **(i)** frequency *f* .... B1 [1]

(ii) amplitude *A* .... B1 [1]

(b) π rad or 180° ....(unit necessary) .... B1 [1]

(c) **(i)** speed = $f \times L$ .... B1 [1]

(ii) wave is reflected at end at P B1
either incident and reflected waves interfere
or two waves travelling in opposite directions interfere M1
speed is the speed of incident or reflected wave / one of these waves .... A1 [3]

[Total: 7]

Q32.

5	**(a)**	when a wave passes through a slit / by an edge	M1	
		the wave spreads out / changes direction	A1	[2]
	(b)	diagram: wavelength unchanged	M1	
		wavefront flat at centre, curving into geometrical shadow	A1	[2]
	(c)	$d \sin \theta = n\lambda$	C1	
		for $\theta = 90°$		
		$1 / (650 \times 10^3) = n \times 590 \times 10^{-9}$	M1	
		$n = 2.6$		
		number of orders is 2	A1	[3]
	(d)	intensity / brightness decreases (as order increases)	B1	[1]

Q33.

5	**(a)**	**(i)**	distance (of point on wave) from rest / equilibrium position	B1	[1]
		(ii)	distance moved by wave energy / wavefront during one cycle of the source **or** minimum distance between two points with the same phase **or** between adjacent crests or troughs	B1	[1]
	(b)	**(i)**	$T = 0.60\,s$	B1	[1]
		(ii)	$\lambda = 4.0\,cm$	B1	[1]
		(iii)	*either* $v = \lambda/T$ *or* $v = f\lambda$ <u>and</u> $f = 1/T$	C1	
			$v = 6.7\,cm\,s^{-1}$	A1	[2]
	(c)	**(i)**	amplitude is decreasing	M1	
			so, it is losing power	A1	[2]
		(ii)	*intensity* ~ *(amplitude)*^{2}	C1	
			ratio = $2.0^2 / 1.1^2$	C1	
			= 3.3	A1	[3]

Q34.

3	connect microphone / (terminals of) loudspeaker to Y-plates of c.r.o.	B1	
	adjust c.r.o. to produce steady wave of 1 (or 2) cycles / wavelengths on screen	B1	
	measure length of cycle / wavelength λ and note time-base b	M1	
	frequency = $1 / \lambda b$	A1	[4]
	(*assume b is measured as s cm^{-1}, unless otherwise stated*)		
	(if statement is 'measure T, f = $1/T$' then last two marks are lost)		

Q35.

6 **(a)** when two (or more) waves meet (at a point) B1
(resultant) displacement is (vector) sum of individual displacements B1 [2]

(b) **(i)** $\lambda = ax / D$ (if no formula given and substitution is incorrect then 0/3) C1
$590 \times 10^{-9} = (1.4 \times 10^{-3} \times x) / 2.6$ C1
$x = 1.1\,\text{mm}$ A1 [3]

(ii) **1.** 180° (*allow* π *if rad stated*) A1 [1]

2. at maximum, amplitude is 3.4 units and at minimum, 0.6 units C1
intensity ~ *amplitude*^{2} allow $I \sim a^2$ C1
ratio = $3.4^2 / 0.6^2$
= 32 A1 [3]

Q36.

6 **(a)** waves overlap B1
(resultant) displacement is the sum of the displacements of each of the waves B1 [2]

(b) waves travelling in opposite directions overlap / incident and reflected waves overlap
(allow superpose or interfere for overlap here) B1
waves have the same speed and frequency B1 [2]

(c) **(i)** time period = 4 × 0.1 (ms) C1
$f = 1 / T = 1 / 4 \times 10^{-4} = 2500\,\text{Hz}$ A1 [2]

(ii) **1.** the microphone is at an antinode and goes to a node and then an antinode / maximum amplitude at antinode and minimum amplitude at node B1 [1]

2. $\lambda / 2 = 6.7\,(\text{cm})$ C1
$v = f\lambda$ C1
$v = 2500 \times 13.4 \times 10^{-2} = 335\,\text{m s}^{-1}$ A1 [3]

incorrect λ then can only score second mark

Q37.

5 **(a)** transverse waves have vibrations that are perpendicular / normal to the direction of energy travel — B1
longitudinal waves have vibrations that are parallel to the direction of energy travel — B1 [2]

(b) vibrations are in a single direction — M1
either applies to transverse waves
or normal to direction of wave energy travel
or normal to direction of wave propagation — A1 [2]

(c) **(i)** **1.** amplitude = 2.8 cm — B1 [1]

2. phase difference = 135° *or* 0.75π rad *or* ¾π rad *or* 2.36 radians
(three sf needed)
numerical value — M1
unit — A1 [2]

(ii) amplitude = 3.96 cm (4.0 cm) — A1 [1]

Q38.

4 **(a)** waves pass through the elements / gaps / slits in the grating — M1
spread into geometric shadow — A1 [2]

(b) **(i)** **1.** displacements add to give resultant displacement — B1
each wavelength travels the same path difference or are in phase — B1
hence produce a maximum — A0 [2]

2. to obtain a maximum the path difference must be λ or phase difference 360° / 2π rad — B1
λ of red and blue are different — B1
hence maxima at different angles / positions — A0 [2]

(ii) $n\lambda = d \sin\theta$ — C1
$N = \sin 61° / (2 \times 625 \times 10^{-9}) = 7.0 \times 10^5$ — A1 [2]

(iii) $n\lambda = 2 \times 625$ is a constant (1250) — C1
$n = 1 \rightarrow \lambda = 1250$ outside visible
$n = 3 \rightarrow \lambda = 417$ in visible
$n = 4 \rightarrow \lambda = 312.5$ outside visible
$\lambda = 420$ nm — A1 [2]

Q39.

4	**(a)** waves (travels along tube) reflect at <u>closed end / end of tube</u>	B1	
	incident and reflected waves or these two waves are in <u>opposite directions</u>	M1	
	interfere or stationary wave formed if tube length equivalent to $\lambda / 4$, $3\lambda / 4$, etc.	A1	[3]
	(b) (i) 1. no motion (as node) / zero amplitude	B1	[1]
	2. vibration backwards and forwards / maximum amplitude along length	B1	[1]
	(ii) $\lambda = 330 / 880$ (= 0.375 m)	C1	
	$L = 3\lambda / 4$	C1	
	$L = 3 / 4 \times (0.375) = 0.28$ (0.281) m	A1	[3]

Q40.

5	**(a)** travel through a vacuum / free space	B1	[1]
	(b) (i) B : name: **microwaves** wavelength: 10^{-4} to 10^{-1} m	B1	
	C : name: **ultra-violet / UV** wavelength: 10^{-7} to 10^{-9} m	B1	
	F : name: **X –rays** wavelength: 10^{-9} to 10^{-12} m	B1	[3]
	(ii) $f = \dfrac{3 \times 10^{8}}{500 \times 10^{-9}}$	C1	
	$f = 6(.0) \times 10^{14}$ Hz	A1	[2]
	(c) vibrations are in one direction	M1	
	perpendicular to direction of propagation / energy transfer or good sketch showing this	A1	[2]

Q41.

5 (a) (i) displacement is the distance the rope / particles are (above or below) from the equilibrium / mean / rest / undisturbed position (not 'distance moved')	B1	[1]
(ii) 1. amplitude (= 80 / 4) = 20 mm	B1	[1]
2. $v = f\lambda$ or $v = \lambda / T$	C1	
$f = 1 / T = 1 / 0.2$ (5 Hz)	C1	
$v = 5 \times 1.5 = 7.5\ \text{m s}^{-1}$	A1	[3]
(b) point A of rope shown at equilibrium position	B1	
same wavelength, shape, peaks / wave moved ¼λ to right	B1	[2]
(c) (i) progressive as energy OR peaks OR troughs is/are transferred/moved /propagated (by the waves)	B1	[1]
(ii) transverse as particles/rope movement is perpendicular to direction of travel /propagation of the energy/wave velocity	B1	[1]

Q42.

5 (a) (i) 1. wavelength: minimum distance between two points moving in phase OR distance between neighbouring or consecutive peaks or troughs OR wavelength is the distance moved by a wavefront in time T or one oscillation/cycle or period (of source)	B1	[1]
2. frequency: number of wavefronts / (unit) time OR number of oscillations per unit time or oscillations/time	B1	[1]
(ii) speed = <u>distance</u> / time = <u>wavelength / time period</u>	M1	
$= \lambda / T = \lambda f$	A0	[1]
(b) (i) amplitude = 4.0 mm (allow 1 s.f.)	A1	[1]
(ii) wavelength = 18 / 3.75 (= 4.8)	C1	
speed = $2.5 \times 4.8 \times 10^{-2} = 12 \times 10^{-2}\ \text{m s}^{-1}$ unit consistent with numerical answer, e.g. in cm s^{-1} if cm used for λ and unit changed on answer line [if 18 cm = 3.5λ used giving speed 13 (12.9) cm s^{-1} allow max. 1].	A1	[2]
(iii) 180° or π rad	A1	[1]
(c) light and screen and correct positions above and below ripple tank	B1	
strobe or video camera	B1	[2]