

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 quantitative 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)  $\lambda = 0.6$  m ..... B1 [1]  
(ii) frequency ( $= v/\lambda$ ) =  $330/0.60$   
= 550 Hz ..... C1  
(use of  $c = 3 \times 10^8 \text{ ms}^{-1}$  scores no marks) ..... A1 [3]
- (b) amplitude shown as greater than  $a$  but less than  $2a$  and constant  
correct phase ..... B1  
(wave to be at least three half-periods, otherwise -1 overall) ..... B1 [2]
- Total [5]

Q3.

- 6 (a) When two (or more) waves meet (not 'superpose' or 'interfere')  
resultant displacement  
is the sum of individual (displacements) ..... B1 [1]  
..... M1  
..... 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  $\theta = x/D$   
 $650 \times 10^{-9} = (a \times 0.70 \times 10^{-3})/1.2$   
 $a = 1.1 \times 10^{-3}$  m ..... C1  
..... C1  
..... 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  
Wave 'bends' into the geometrical shadow/changes direction/spreads  
M1  
A1 [2]
- (b) (i)  $d = 1/(750 \times 10^3)$   
 $= 1.33 \times 10^{-6} \text{ m}$   
C1  
A1 [2]
- (ii)  $1.33 \times 10^{-6} \times \sin 90^\circ = n \times 590 \times 10^{-9}$   
 $n = 2$  (must be an integer)  
C1  
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)  
(if differences stated but without reference to the orders, max 1 mark)  
B2 [2]

Q5.

- 6 (a) (i) correct shape drawn  
B1 [1]
- (ii) two nodes marked correctly  
B1 [1]
- (b)  $\frac{1}{2}\lambda = 0.324 \text{ m}$   
 $v = f\lambda$   
 $= 512 \times 2 \times 0.324$   
 $= 332 \text{ m s}^{-1}$   
C1  
C1  
A1 [3]
- (c)  $\frac{1}{4}\lambda = 16.2 \text{ cm}$   
*either* antinode is 0.5 cm above top of tube  
*or* antinode is 16.2 cm above water surface  
C1  
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)  $2.5\lambda = 39 \text{ cm}$  C1  
 $v = f\lambda$  C1  
 $v = 2.14 \times 10^3 \times 15.6 \times 10^{-2}$   
 $= 334 \text{ m s}^{-1}$  (allow 330, not 340) A1 [3]
- (c) Stationary wave formed by interference / superposition / overlap of B1  
either wave travelling down tube and its reflection B1  
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 of the source / of a point on the wave M1  
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 =  $2 \times 17.8 = 35.6 \text{ cm}$  C1  
 $v = f\lambda$  C1  
 $v = 125 \times 0.356$   
 $= 44.5 \text{ m s}^{-1}$  C1  
 $44.5^2 = 4.00 / m$  C1  
 $m = 2.0 \times 10^{-3} \text{ kg m}^{-1}$  A1 [5]

Q8.

- 5 (a) either phase difference is  $\pi \text{ rad} / 180^\circ$   
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  $S_2 = 28 \text{ cm}$  B1  
wavelength changes from 33 cm to 8.25 cm B1  
minimum when  $\lambda = (56 \text{ cm},) 18.7 \text{ cm}, 11.2 \text{ cm}, (8.0 \text{ cm})$  B1  
so two minima B1 [4]

Q9.

- 5 (a) constant phase difference ..... B1 [1]
- (b) allow wavelength estimate 750 nm  $\rightarrow$  550 nm ..... C1  
 separation =  $\lambda D / x$  ..... C1  
 $= (650 \times 10^{-9} \times 2.4) / (0.86 \times 10^{-3})$   
 $= 1.8 \text{ mm}$  ..... A1 [3]  
 (allow 2 marks from inappropriate estimate if answer is in range 10 cm  $\rightarrow$  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)  $\tan \theta = \frac{38}{165}$   
 $\theta = 13^\circ$  ..... 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  $90^\circ$  ..... 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) $\lambda = (330 \times 10^2)/550$ .....	M1	
$\lambda = 60 \text{ cm}$ .....	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 = $\lambda/4$ .....	C1	
$\lambda = 1.8 \text{ m}$ .....		
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) $v = \text{distance} / \text{time} = n\lambda/t$	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 $3 \times 2 = 6.0 \text{ ms}$	C1	
frequency = $1/(6 \times 10^{-3}) = 170 \text{ Hz}$	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.  $360^\circ / 2\pi$  rad allow  $n \times 360^\circ$  or  $n \times 2\pi$  (unit missing -1) B1 [1]  
 2.  $180^\circ / \pi$  rad allow  $(n \times 360^\circ) - 180^\circ$  or  $(n \times 2\pi) - \pi$  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  
 $= 639 \text{ nm}$  A1 [3]

Q15.

- 6 (a) (i) amplitude = 7.6 mm allow 7.5 mm A1 [1]
- (ii)  $180^\circ / \pi$  rad A1 [1]
- (iii)  $v = f \times \lambda$  C1  
 $= 15 \times 0.8$  A1 [2]  
 $= 12 \text{ ms}^{-1}$
- (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  $\lambda$  or  $n\lambda$   
 or phase difference is  $360^\circ$  or  $n \times 360^\circ$  or  $n2\pi$  rad B1 [1]

- (iii) path difference is *either*  $\lambda/2$  or  $(n + \frac{1}{2}) \lambda$   
 or phase difference is odd multiple of *either*  $180^\circ$  or  $\pi$  rad B1 [1]
- (iv)  $w = \lambda D / a$  C1  
 $= [630 \times 10^{-9} \times 1.5] / 0.45 \times 10^{-3}$  C1  
 $= 2.1 \times 10^{-3} \text{ m}$  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 =  $\lambda / 2 = 34 \text{ cm}$  (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)  $d \sin \theta = n\lambda$   
 $n = d / \lambda = 1 / 450 \times 103 \times 630 \times 10^{-9}$  C1  
 $n = 3.52$  M1  
 hence number of orders = 3 A1 [3]
- (c)  $\lambda$  blue is less than  $\lambda$  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  $\lambda$  or frequency*) (B1)  
 path difference = 0,  $\lambda$ ,  $2\lambda$  or phase difference = 0,  $2\pi$ ,  $4\pi$  (B1)  
 same direction of polarisation/unpolarised (B1)  
 max. 3 [3]
- (b)  $\lambda = v / f$  C1  
 $f = 12 \times 10^9 \text{ Hz}$  C1  
 $\lambda = 3 \times 10^8 / 12 \times 10^9$  (*any subject*) M1  
 $= 0.025 \text{ m}$  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  
 $\lambda = 40 / 50 = 0.8(0) \text{ m}$  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)  $(1.5\lambda$  for PQ hence  $PQ = 0.8 \times 1.5) = 1.2 \text{ m}$  A1 [1]
- (iii)  $T = 1 / f = 1/50 = 20 \text{ ms}$  C1  
 5 ms is  $\frac{1}{4}$  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 =  $180^\circ / (n + \frac{1}{2}) 360^\circ$  (allow in rad) B1 [1]  
2. phase difference =  $0 / 360^\circ / (n360^\circ)$  (allow in rad) B1 [1]
- (ii)  $v = f\lambda$  C1  
 $\lambda = 320 / 400 = 0.80 \text{ m}$  A1 [2]
- (iii) path difference =  $7 - 5 = 2 \text{ (m)}$   
 $= 2.5\lambda$  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  $60^\circ$  correct .. (need to see  $1\frac{1}{2}$  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.  $-\frac{1}{2}A$  ..... B1  
2.  $\frac{1}{2}A$  ..... (allow e.c.f.) ..... B1  
3. zero ..... (allow e.c.f.) ..... B1 [3]

Q23.

- 4 (a) (i)1 amplitude =  $0.4(0) \text{ mm}$  ..... A1
- (i)2 wavelength =  $7.5 \times 10^{-2} \text{ m}$   
(1 sig. fig. -1 unless already penalised) ..... A1
- (i)3 period =  $0.225 \text{ ms}$  ..... C1  
frequency =  $1/T = 4400 \text{ Hz}$  ..... A1
- (i)4  $v = f\lambda$   
 $= 4400 \times 7.5 \times 10^{-2}$  ..... C1  
 $= 330 \text{ m s}^{-1}$  ..... A1 [6]

(a)	(ii)	reasonable shape, same amplitude and wavelength doubled .....	B1	[1]
(b)	(i)	$1.7(2) \mu\text{m}$ .....	A1	
	(ii)	$d \sin 2 = n\lambda$ (double slit formula scores 0/2) $1.72 \times 10^{-6} \times \sin 2 = 590 \times 10^{-9}$ .....	C1	
		$2 = 20.1^\circ$ (allow $20^\circ$ ) .....	A1	
	(iii)	$\frac{1}{2}L = 1.5 \tan 20.1$ .....	C1	
		$L = 1.1 \text{ m}$ .....	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)		<b>B3 [3]</b>
	(b)	$495 \text{ nm} = 495 \times 10^{-9} \text{ m}$		<b>C1</b>
		number = $1/(495 \times 10^{-9}) = 2.02 \times 10^6$		<b>A1 [2]</b>
		(allow 2 or more significant figures)		
	(c) (i)	allow $10^{-7} \rightarrow 10^{-11} \text{ m}$		<b>B1</b>
	(ii)	allow $10^{-3} \rightarrow 10^{-6} \text{ m}$		<b>B1 [2]</b>

Q25.

- 4 (a) wavelength = 1.50 m B1 [1]
- (b)  $v = f \lambda$  C1
- speed = 540 m s<sup>-1</sup> 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 =  $1.0 \times 10^{-4}$  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 C1
- allow  $\pm 0.5 \times 10^{-4}$  cm
- resultant displacement = (-)  $0.9 \times 10^{-4}$  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)
- $\theta$  is greater so  $\lambda$  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  $\pm\frac{1}{2}$  square) B2  
B1 [3]
- (b)  $\lambda = ax / D$  C1  
 $540 \times 10^{-9} = (0.700 \times 10^{-3} x) / 2.75$  C1  
 $x = 2.12 \text{ mm}$  A1 [3]
- (c) (i) same separation B1  
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 B2 [3]
- (ii) smaller separation of fringes B1  
no change in brightness B1 [2]

Q29.

- 6 (a) wave incident at an edge / aperture / slit / (edge of) obstacle M1  
bending / spreading of wave (into geometrical shadow) A1 [2]  
(award 0/2 for bending at a boundary)
- (b) (i) apparatus e.g. laser & slit / point source & slit / lamp and slit & slit  
microwave source & slit  
water / ripple tank, source & barrier B1  
detector e.g. screen  
aerial / microwave probe  
strobe / lamp B1  
what is observed B1 [3]
- (ii) apparatus e.g. loudspeaker, and slit / edge B1  
detector e.g. microphone & c.r.o. / ear B1  
what is observed 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 .....M1  
or distant source ..... A1  
light region where darkness expected ..... B1
- 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)  $\pi$  rad or  $180^\circ$  .....(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 .....M1  
or two waves travelling in opposite directions interfere ..... A1 [3]  
speed is the speed of incident or reflected wave / one of these waves
- [Total: 7]

Q32.



- 5 (a) when a wave passes through a slit / by an edge  
the wave spreads out / changes direction M1  
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  $\theta = 90^\circ$   
 $1 / (650 \times 10^3) = n \times 590 \times 10^{-9}$  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)  $T = 0.60\text{ s}$  B1 [1]
- (ii)  $\lambda = 4.0\text{ cm}$  B1 [1]
- (iii) either  $v = \lambda/T$  or  $v = f\lambda$  and  $f = 1/T$  C1  
 $v = 6.7\text{ cm s}^{-1}$  A1 [2]
- (c) (i) amplitude is decreasing  
so, it is losing power M1  
A1 [2]
- (ii)  $\text{intensity} \sim (\text{amplitude})^2$  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  $\lambda$  and note time-base  $b$  M1  
frequency =  $1 / \lambda b$  A1 [4]  
(assume  $b$  is measured as  $\text{s cm}^{-1}$ , 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)  
(resultant) displacement is (vector) sum of individual displacements B1  
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.  $180^\circ$  (allow  $\pi$  if rad stated) A1 [1]
2. at maximum, amplitude is 3.4 units and at minimum, 0.6 units C1  
 $\text{intensity} \sim \text{amplitude}^2$  allow  $I \sim a^2$  C1  
 $\text{ratio} = 3.4^2 / 0.6^2$   
 $= 32$  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 =  $4 \times 0.1 \text{ (ms)}$  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  
 $v = 2500 \times 13.4 \times 10^{-2} = 335 \text{ ms}^{-1}$  A1 [3]
- incorrect  $\lambda$  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 A1 [2]  
or normal to direction of wave propagation
- (c) (i) 1. amplitude = 2.8 cm B1 [1]  
2. phase difference =  $135^\circ$  or  $0.75\pi$  rad or  $\frac{3}{4}\pi$  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 spread into geometric shadow M1  
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  $\lambda$  or phase difference  $360^\circ / 2\pi$  rad B1  
 $\lambda$  of red and blue are different B1  
hence maxima at different angles / positions A0 [2]
- (ii)  $n\lambda = d \sin \theta$  C1  
 $N = \sin 61^\circ / (2 \times 625 \times 10^{-9}) = 7.0 \times 10^5$  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 closed end / end of tube  
incident and reflected waves or these two waves are in opposite directions  
interfere or stationary wave formed if tube length equivalent to  
 $\lambda / 4, 3\lambda / 4$ , etc. B1  
M1  
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)  $\lambda = 330 / 880 (= 0.375 \text{ m})$  C1  
 $L = 3\lambda / 4$  C1  
 $L = 3 / 4 \times (0.375) = 0.28 (0.281) \text{ m}$  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)  $f = \frac{3 \times 10^8}{500 \times 10^{-9}}$  C1  
 $f = 6(0) \times 10^{14} \text{ Hz}$  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  $(= 80 / 4) = 20 \text{ mm}$  B1 [1]
2.  $v = f\lambda$  or  $v = \lambda / T$  C1  
 $f = 1 / T = 1 / 0.2 \text{ (5 Hz)}$  C1  
 $v = 5 \times 1.5 = 7.5 \text{ ms}^{-1}$  A1 [3]
- (b) point A of rope shown at equilibrium position B1  
 same wavelength, shape, peaks / wave moved  $\frac{1}{4}\lambda$  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 =  $\frac{\text{distance}}{\text{time}} = \frac{\text{wavelength}}{\text{time period}}$  M1  
 $= \lambda / T = \lambda f$  A0 [1]
- (b) (i) amplitude =  $4.0 \text{ mm}$  (allow 1 s.f.) A1 [1]
- (ii) wavelength =  $18 / 3.75 (= 4.8)$  C1  
 speed =  $2.5 \times 4.8 \times 10^{-2} = 12 \times 10^{-2} \text{ ms}^{-1}$  unit consistent with numerical answer, e.g. in  $\text{cm s}^{-1}$  if cm used for  $\lambda$  and unit changed on answer line A1 [2]  
 [if  $18 \text{ cm} = 3.5\lambda$  used giving speed  $13 (12.9) \text{ cm s}^{-1}$  allow max. 1].
- (iii)  $180^\circ$  or  $\pi \text{ rad}$  A1 [1]
- (c) light and screen and correct positions above and below ripple tank B1  
 strobe or video camera B1 [2]