1)

Question			Expected Answers	Marks	Additional Guidance
	a	i	when (two) waves meet/combine/interact/superpose, etc. (at a point) there is a change in overall intensity/displacement	M1 A1	**allow** for A1 mark: (vector) sum/resultant displacement(s)/AW
		ii	constant phase difference/relationship (between the waves)	B1	just stating same frequency **not** sufficient
	b	i	path difference of $n\lambda$ for constructive interference producing **either** maximum amplitude/intensity **or** a maximum path difference of $(2n + 1)\lambda/2$ for destructive interference producing **either** minimum amplitude/intensity **or** a minimum	M1 A1 M1 A1	**allow** waves arrive in phase **allow** waves arrive in anti-/out of phase **max** 3 marks; max 1 mark for two correct marking points but with n omitted
		ii	$x = \lambda D/a = 0.030 \times 5.0/0.20$ $=0.75$ (m)	C1 A1	**give** 1 mark max for 0.75 mm but zero for 750 m
		iii 1	intensity increases by factor of 4 position unchanged	B1 B1	
		2	intensity unchanged distance apart of maxima is doubled	B1 B1	
		3	intensity unchanged maxima move to positions of minima (and vice versa)	B1 B1	
			Total question 6	**14**	

2)

(a)		**is a transfer of energy** as a result of oscillations (of the source/medium/particles through which energy is travelling)	**M1** A1	**allow** carries **allow** information **accept** without the transfer of the medium/particles/matter
(b)		displacement/oscillation (of particles) is normal/perpendicular to direction of energy transfer in transverse wave displacement/oscillation (of particles) is parallel to direction of energy transfer in longitudinal wave	B1 B1	**allow** vibrations **allow** to direction of wave motion/propagation/velocity/travel **NOT** transverse wave can travel through a vacuum give max 1 mark for 2 similar poor definitions, e.g. direction of travel, waves oscillate, etc. (two such errors scores zero)
(c)	(i)	wavefronts/paths spread out after passing through a gap or around an obstacle/AW	B1	**NOT** wave changes direction
	(ii)	use a slit/hole/ barrier width of gap/position beyond barrier comparable to wavelength microphone/observer's ear suitably placed sound detected/heard outside 'geometrical shadow' region (showing diffraction)	B1 B1 B1 B1	**accept** doorway/end of wall **accept** position of detector beyond doorway **N.B.** good diagram can illustrate first 3 marking points **allow** 'hears sound' in suitable context only observation mark which is QWC mark must be in words 2 marks max for double slit experiment(1^{st} and 3^{rd} m.p.)
(d)	(i)	$v = f\lambda$ giving $340 = 1200 \times \lambda$ $\lambda = 0.28$ (m)	C1 A1	substitution needed to score mark POT error for using 1.2 kHz giving 280 m **N.B.** $\lambda = 0.3$ SF error (remember apply only once)
	(ii)	waves superpose/interfere at points along **PQ** (constructively and destructively) path difference from sources of $n\lambda$ for maximum/loud sound/intensity path difference of $(2n + 1)\lambda/2$ for minimum/quiet sound/intensity	B1 B1 B1	**max** 2/3 for writing phase difference is $n\lambda$ or path difference is 2π i.e. mixing path and phase consistently through answer **allow** waves arrive in phase (0, 2π, 360^o, etc) **allow** waves arrive in anti-phase (π, 180^o, etc) **do not allow** waves arrive out of phase **or** answers in terms of peaks and troughs for 2^{nd} and 3^{rd} marks
	(iii)	$a = \lambda D/x$ giving $a = 0.28 \times 3.0/0.50$ $a = 1.7$ m	C1 A1	**ecf (d)(i)** substitution needed to score mark
	(iv)	intensity of sound (at maxima) unchanged/AW positions of maxima and minima reversed/AW	B1 B1	**allow** volume or amplitude
		Total	**18**	

3)

a	**i**	method of producing coherent sources at S_1 and S_2 light (waves) from the two slits/sources must be coherent; that is, they must have a constant phase relationship/difference slits must be narrow/close together (so that diffraction patterns overlap) light (waves) from two slits must have similar amplitudes/intensities	B1 B1 B1 B1 B1	e.g. initial single slit **max 3 marks** from 5 marking points
	ii	*bright*: constructive interference occurs/waves add to give a maximum amplitude at the screen path difference between slits and screen is a whole/integer number of wavelengths/waves arrive in phase at screen *dark*: destructive interference occurs/waves add to give a minimum amplitude/zero at the screen path difference between slits and screen is an odd half number of wavelengths/waves arrive out of/in antiphase at screen	B1 B1 B1 B1	 **accept** explanation in terms of distance or phase **accept** explanation in terms of distance or phase
b	**i**	7.4/5 = 1.48 x 10^{-3} (m)	B1	**accept** 1.5 mm
	ii	λ = xd/L = 1.48 x 10^{-3} x 0.6 x 10^{-3}/1.5 = 5.9(2) x 10^{-7} (m)	C1 C1 A1	using 1.5 mm gives 600 nm **ecf(b)(i)** e.g. 4 92 x 10^{-7} for 1.23 mm **accept** 590 nm
c		pattern/fringes vanish because there is now no interference from light from the two slits/AW light spreads out over whole/similar region light intensity (at screen) is less diffraction spreads light simple description of single slit pattern further features of single slit pattern	B1 B1 B1 B1 B1 B1 B2	 e.g. bright in middle and dim at edges/sketch of bell shape **max 3 marks** from 8 marking points
		Total question 6	**14**	

4)

(a)		light from the two sources must be/slits is coherent only possible to produce constant phase difference using a single source	B1 B1	**allow** 'has a constant phase difference' for 'is coherent' **allow** separate light sources are not coherent/do not have a constant phase difference
(b)		at D: 180° **or** π rad at B: 0 or 360° **or** 2π rad	B1 B1	**max** 1 out of 2 if unit omitted except on zero **allow** ^{c} as symbol for rad
(c)	**(i)**	2.0 x 10^{-3} (m)	B1	**allow** 1 SF and 2 mm; **allow** 1.8 or 1.9 mm, **only** 2 SF
	(ii)	λ = ax/D = 0.4 x 10^{-3} x 2.0 x 10^{-3} /1.5 = 5.3(3) x 10^{-7} (m)	C1 C1 A1	select formula **ecf c(i)**; substitute answer
(d)		2 λ 1060 (nm)	C1 A1	**ecf c(ii); allow** 1000 for 5 x 10^{-7} **allow** 1066, 1067, 1070,1100
(e)	**(i)**	E = (8.7 x 10^{-19} – 5.0 x 10^{-19}) = 3.7 x 10^{-19} (J) select E = hc/ λ E = 6.63 x 10^{-34} x 3.0 x 10^8/5.3 x 10^{-7} = 3.73 x 10^{-19} (J) [or 3.98 x 10^{-19} if using 5.0 x 10^{-7}]	B1 C1 M1 A1	readings from diagram must see substitution **ora** substitute for E and find λ calculation **ora** 5.4 x 10^{-7} (m) **N.B.** the B mark can be awarded inside the calculation **only** for the **ora** method
	(ii)	**X** in infra-red/ir **Z** in ultra-violet/uv	B1 B1	**allow** 1 mark for answers reversed
		Total	**16**	

5)

a		constant phase difference/relationship (between the waves) **or** always at π radians/180° **or** because they are generated by the same source/AW	**B1**	**allow** fixed **NOT** same
b		(for a minimum) the two oscillations/amplitudes add in antiphase/ are π (rad) out of phase/completely out of phase there is a resultant amplitude (of 2.0 μm) so a sound will still be heard	**B1** **B1**	for zero intensity the two oscillations must have equal amplitudes/AW and be in antiphase **allow** the word waves for oscillations
c		**B** π/2 radians/90° **C** 3π/4 radians/135°	**B1** **B1**	**max** 1 out of 2 marks if unit omitted
d	**i**	$f = 10^3/0.8 = 1.25$ kHz **or** $T = 0.8 \times 10^{-3}$ s $\lambda = v/f$ **or** $vT = 340 \times 0.8 \times 10^{-3}$ $\lambda = 0.27$ m	**C1** **C1** **A1**	if T value from graph incorrect **ecf** with max 2/3
	ii	select $\lambda = ax/D$ $D = 0.4 \times 4.8/0.27$ $D = 7.1$ (m)	**C1** **C1** **A1**	**ecf (d)(i)** **expect** 7.06 m if using $\lambda = 0.272$ m 3.5 m or 3.6 m scores 2 marks
e	**i**	energy per unit time/power per unit area (perpendicular to the direction of energy transfer)	**B1**	**accept** per second as a special case
	ii	ratio of amplitudes = 3 intensity is proportional to (amplitude)^2 ratio of intensities = 9 so intensity at **O** = $4.0 \times 10^{-6} \times 9$ $I = 3.6 \times 10^{-5}$ (W m^{-2})	**C1** **C1** **A1**	**or** A at **P** = 2.0 μm and A at **O** = 6.0 μm clearly stated **allow** $I \propto A^2$ i.e. symbols only
		Total	**15**	

6)

a	**i**	when two (or more) waves meet/superpose/overlap (at a point) there is a change in overall displacement	M1 A1	**NOT** interact,combine, join, connect, collide, hit, intersect, pass through, etc. **allow** the resultant displacement equals the sum of the individual displacements
	ii	constant phase difference/relationship (between the waves)	B1	**allow** fixed **not** same
b		$\lambda = c/f = 3.0 \times 10^8 / 1.0 \times 10^{10}$ $\lambda = 3.0 \times 10^{-2}$ so aerial length = 1.5×10^{-2} (m)	M1 A1	 **accept** 1.5 c(m)
c	**i1**	the path difference between the signals (from the two transmitters) changes (along OP) causing the detected signal to vary between maximum and minimum values/AW **or** when signals (at the point on OP) are in phase there is a maximum when (π) out of phase there is a minimum	B1 B1	**give** 1 mark out of 2 for maxima and minima occur (because of interference)
	2	$x = \lambda D/a = 3.0 \times 10^{-2} \times 4.0/0.20$ (= 0.60) so distance = x/2 = 0.30 (m)	C1 A1	**ecf (b)** 20 times answer to **(b)** **allow** 1 SF answer here
	ii	amplitude of signal decreases (inversely) with distance because energy emitted by the transmitters spreads out (so less is collected by the receiver the further away it is)	B1 B1	**allow** intensity; **no mark if** any suspicion of decrease being caused by interference effect **accept** any statement which conveys the idea of energy spreading correctly,e.g. $I \propto 1/d^2$
	iii	when AO – BO = λ/2 a minimum occurs/AW **or** phase difference of π (180°) between detected signals from A and B so distance = λ/2 = 1.5×10^{-2} (m)	B1 B1	idea that movement of λ/2 will change maximum to minimum or vice versa **ecf (b)** same answer as **(b); accept** 1.5 c(m)
d	**i**	intensity increases by factor of 4 as intensity α (amplitude)^2	B1 B1	
	ii	intensity falls to zero (emitted) signal is (vertically) polarised receiver in position only to detect horizontally polarised signal	B1 B1 B1	 **allow** transmitter and detector act like 'crossed polarisers' or quoting Malus' law correctly
		Total question 5	**18**	