Question			Answer	M	Guidance
1					
	a	**i 1**	the maximum displacement <u>from equilibrium</u> or <u>rest position</u>	B1	**allow** *zero* or *undisturbed* for *equilibrium*
		2	number of oscillations/vibrations (at a point) <u>per</u> unit time	B1	number of <u>wavelengths</u> passing a point or produced by the wave source <u>per</u> unit time **allow** <u>per</u> second **NOT** *amount* for *number*
		3	how far 'out of step' (out of sync) the oscillations <u>at two points</u> on the wave/string are/AW	B1	**alt e.g.** the fraction of a cycle between the oscillations at the two points
		ii 1	all have same frequency **or** same amplitude	B1	**N.B.** withhold mark if extra incorrect answers given
		2	all have different phases/ phase differences	B1	**allow** *not in phase* or *all out of phase*
	b	**i**	*progressive* a wave which transfers energy *stationary* a wave which <u>traps/stores</u> energy (in pockets) **or** *progressive* : transfers shape/information from one place to another *stationary* where the shape does not move along/which has nodes and antinodes/AW	B1 B1	**accept** phase relationship descriptions between different points on wave; must be a comparison for same property to score both marks
		ii	the wave <u>reflected</u> (at the fixed end of the wire) <u>interferes/superposes</u> with the incident wave to produce a resultant wave with nodes and antinodes/no energy transfer	B1 B1 B1	
		iii 1	**(all** points have) same frequency	B1	
			P and **Q** have same amplitude <u>and</u> (are in) phase	B1	**allow** *same phase difference* here
		2	**S** has larger amplitude than **P** <u>and</u> **Q**	B1	**allow** *different to*
			S has a phase difference of π/in antiphase to **P** <u>and</u> **Q**	B1	**or** 180^{o} **max** any 3 out of 4 marking points
		iv 1	15 Hz	B1	
			as all points in the fundamental/first harmonic mode move in phase	B1	**accept** string is ½ λ long/between ends
		2	120 Hz	B1	
			for every 10 cm to be at rest λ = 20 cm (so 4 x frequency of Fig. 4.2)	B1	**accept** as all points are nodes **or** f = $8f_0$ **or** is 8^{th} harmonic
			Total question 4	**17**	

Question			Answer	M	Guidance
2					
	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 <u>and</u> 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^{o}) between detected signals from A and B so distance = $\lambda/2 = 1.5 \times 10^{-2}$ (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) <u>polarised</u> 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**	

Question			Answer	Marks	Guidance
3	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 x 10^{-3} s λ = v/f **or** vT = 340 x 0.8 x 10^{-3} λ = 0.27 m	**C1** **C1** **A1**	if T value from graph incorrect **ecf** with max 2/3
		ii	select λ = ax/D D = 0.4 x 4.8/ 0.27 D = 7.1 (m)	**C1** **C1** **A1**	**ecf (d)(i)** **expect** 7.06 m if using λ = 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 x 10^{-6} x 9 I = 3.6 x 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 α A^2 i.e. symbols only
			Total	**15**	