1. (i) λ distance between (neighbouring) identical points/points with same phase (on the wave)

accept peak/crest to peak/crest, etc.

B1

f number of waves passing a point /cycles/vibrations (at a point) per unit time/second

accept number of waves produced by the wave source per unit time/second

B1

v distance travelled by the wave (energy) per unit time/second

not *$v = f\lambda$ and not 'in one second'*

B1

(ii) in 1 second f waves are produced each of one wavelength λ

accept *time for one λ to pass is 1/f so $v = \lambda/(1/f) = f\lambda$*

M1

distance travelled by first wave in one second is $f\lambda = v$

give *max 1 mark for plausible derivations purely in terms of algebra (no words)*

A1

[5]

2. (i) it consists of nodes and antinodes / it does not transfer energy (WTTE) B1
formed by two identical waves travelling in opposite directions (WTTE) B1
(microwaves leaving transmitter) interfere (with reflected waves) (WTTE) B1
{allow superimpose/interact/cancel out/reinforce for interfere}

(ii) 1.wavelength of the microwaves = 2 × 1.4 = 2.8 cm B1

2. speed of microwaves in air = 3 × 108 m/s OR c M1
frequency = 3 × 108 /2.8 × 10 – 2 (allow ecf) = 1.07 × 1010 Hz A1

(iii) Place a metal grid {allow "Polaroid"} (between T and D) and rotate
(or place at 900) OR rotate grid/transmitter/detector B1
this causes minm/zero signal (WTTE) B1

[8]

3.	(a)	(i)	amplitude correctly labelled (by **A** or in words) (reject "A" as a point i.e. with no arrows)	B1
		(ii)	wavelength correctly labelled (by **λ** or in words)	B1
	(b)	(i)	same shape moved slightly to the right consistently drawn for both waves (do not allow shift of more than ¼ wavelength)	B1 B1
		(ii)	movement is VERTICAL Q moves UP ↑ AND S moves DOWN ↓ shown	M1 A1
	(c)		phase difference = 180° (degrees) OR π {allow "in antiphase" do not allow "out of phase"}	B1
	(d)	(i)	recall of T = 1/f	C1
			T = 1/25 = 0.04 s	A1
		(ii)	recall of v= fλ valid substitution: e.g. v = 25 × .036 v = 0.90 ms^{-1}	C1 C1 A1
			(there are 2 possible errors – incorrect wavelength and wrong units, so v = 90 m/s scores 2 marks v = 0.45 m/s scores 2 marks but allow 3 marks for ecf from cand's λ in (a) (ii) v = 45 m/s scores 1 mark but allow 2 marks for ecf from cand's λ in (a) (ii)	
	(e)	(i)	any valid suggestion: e.g. change depth of water	B1
		(ii)	wavelength will reduce halved {OR new wavelength = 1.8cm OR half cand's value shown in (d) ii}	C1 A1

[15]

4. e.g. all are transverse waves (1)
so all can be polarised (under suitable conditions) (1)
all can travel in a vacuum (1)
at the same speed (1)

MAXIMUM 2 for first part 2

Discussion of other wave phenomena and how they change as wavelength changes
e.g. diffraction
refraction
or such things as
the sensitivity of the eye to certain wavelengths
photographic film for certain wavelengths
heating effect, particularly of infra-red
radio and its effect on electrons
quantum effects – minimal for radio, predominant for gamma

4 marks can be given as 2,2 or 2,1,1 4

i.e. 2 topics dealt with fully or (1) topic dealt with fully and 2 topics outlined

[6]

5. (i) infra red is part of the e-m spectrum

B1

lower f **or** longer λ than the visible region/light **or** suitable value or range of λ

accept *any single λ in range* 10^{-5} *m to* 7.5×10^{-7} *m or any reasonable wider range*

B1

(ii) **1** $\lambda = c/f = 3.0 \times 10^{8} / 6.7 \times 10^{13}$

C1

4.5×10^{-6} (m)

accept 4.48×10^{-6} *or more s.f.*

A1

2 $T = 1/f = 1/6.7 \times 10^{13}$

C1

$T = 1.5 \times 10^{-14}$ (s)

accept 1.49×10^{-14}

A1

(iii) at least one cycle of a sine or cosine curve as judged by eye

ecf (ii)2 **B1**

amplitude 8.0×10^{-12} m **B1**

period = 1.5×10^{-14} s **B1**

[9]

6. (i) period = 1/500 = 0.002s (or 2ms) B1

(ii) at least 2 full (sine) waves of constant period (+/– 2mm) B1
of amplitude 3 cm (+/– 2mm in both directions) B1
correct 'period' of 4 cm (+/– 2mm throughout) B1

(iii) correct substitution into $v = f\lambda$: e.g. $330 = 500\lambda$ C1
$\lambda = 0.66$ m {do not allow 0.6 but allow 0.7} A1

[6]

7. (i) wave sources with constant phase difference B1

{NB allow "in phase" and ignore reference to frequency/wavelength/amplitude}

(ii) S_1 and S_2 'share the same light' (AW) B1

reference to diffraction at the single slit
OR to wavefronts e.g. "same wavefront reaches S_1 and S_2 (AW) B1

(iii) Constructive interference occurs at O B1
path difference is zero OR waves meet in phase (AW) B1

(iv) recall of formula $\lambda = ax/D$ in any valid form (e.g. $x = \lambda D/a$) C1

{NB allow undefined symbols provided they match the above as stated in the spec., otherwise they must be defined}

correct sub. with consistent units: $\lambda = 2 \times 10^{-3} \times 0.6 \times 10^{-3} / 1.8$ C1
$\lambda = 6.7 \times 10^{-7}$ m A1

{NB allow ecf if mm used: i.e 2 marks for 6.7×10^{-1} OR 6.7×10^{-4}}

(v) 'fringe separation' (AW) would DECREASE B1

{NB allow "more fringes would be seen"}

because $x \propto \lambda$ (AW) B1

{NB allow 'colour change' arguments for full marks:

Colour would change B1;
to a colour closer to the blue end of visible spectrum (AW) B1}

[10]

8. (i) arrows show vertical oscillations B1
maximum amplitude at top {allow ecf for horiz.} B1
less in middle AND very small (or zero) at base B1
{allow 1 mark only for unlabelled diagram showing representation of amplitude}
{2 marks for unlabelled diagram plus an arrow}
{allow single headed arrows}

(ii) wavelength = 4 × 0.36 = 1.44m B1

(iii) recall of $v = f\lambda$ B1
$f = v/\lambda$ = 330/1.44 (allow ecf) = 229 (or 230) Hz B1

(iv) if open at both ends each end must be an antinode OR diagram B1
hence wavelength = 0.72m {allow ecf} C1
and frequency = 458 (or 460) Hz {allow ecf} A1

[9]

9. when two waves meet/overlap/interfere/collide/superpose (AW) B1
the resultant displacement is the sum of the displacements B1
{do not allow amplitude}
{NB allow 2 marks for good diagrams}

[2]