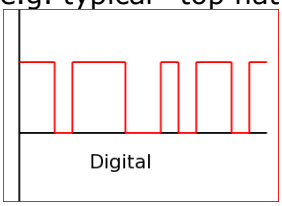
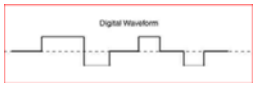
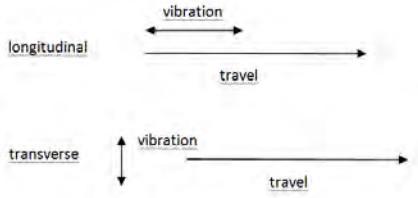
Question number	Answer	Notes	Marks
1 (a)	B - light;		1
(b) (i)	(signal has) two values;	accept • on or off • 0 and 9 • 0 and 1 • 1 and 9 • two signal strengths/states • binary • it is a square wave(form) ignore • all at 9 • up and down • true and false	1
(ii)	any two of: MP1. (idea of) increasing the bit rate / sending more bits in the same time; MP2. (idea of) an **additional** level / strength; MP3. (idea of) increased bandwidth / range of transmission frequencies; MP4. (idea of) multiplexing; MP5. (idea of) quantisation (algorithm);	ignore references to analogue signals allow more bits / pulses per second condone increase frequency allow a named **extra** level e.g. 'use 4.5 as well' allow wider bandwidth ignore 'broadband' allow use more than one channel condone add extra signals allow compression of data	2

Total 4 marks

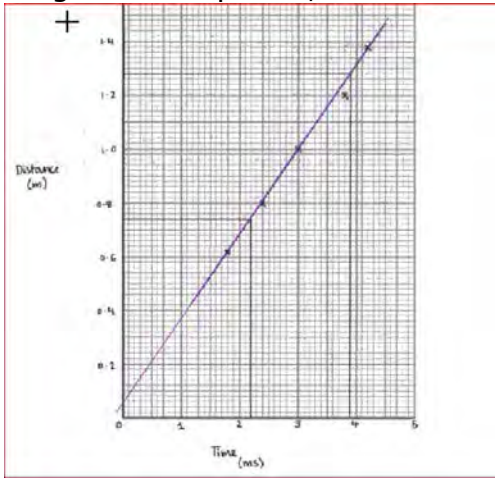
Question number	Answer	Notes	Marks
2 (a)	2 value line with top line & lower line at constant heights; straight up/down lines; e.g. typical 'top hat' waveform  	ignore spacing of pulses judge by eye allow waveform with 3 distinct values at +X, zero and – X 	2
(b)	any two described **advantages** from:- MP1. information density e.g. digital carry more information (per second); MP2. quality e.g. maintain quality over longer distances; MP3. easier to reduce noise/less affected by noise; MP4. regeneration e.g. able to boost signal to original strength;	accept clearer easier to process total marks = 4	2

Question number			Answer	Notes	Marks
3	a	i	number of waves/cycles = 3.5; $\frac{0.60}{3.5}$ = 0.17 (m);	3.5 seen or implied 0.1714 (m) 17 cm 17.14 cm For 1 mark only 17 (m), 17.14(m), 0.2 (m), 0.15 (m), 0.085 (m)	2
		ii	wave speed = frequency x wavelength	allow words or accepted symbols and rearrangements	1
		iii	substitution; rearrangement; evaluation; eg. $3.0 \times 10^8 = 0.17 \times f$ (1 mark) $3.0 \times 10^8 / 0.17$ (2 marks) 1.8×10^9 (Hz) (3 marks)	**allow ecf from ai** 1.76×10^9 (Hz) 1.75×10^9 (Hz) POT = -1	3
	b	i	diffraction;		1
		ii	any two from: MP1. microwaves not diffracted as much; MP2. diffraction (only seen) when size of barrier/gap comparable to wavelength; MP3. radio-waves have (much) longer wavelength than microwaves/RA;	 must have quantifier-e.g 'little' ignore 'microwaves not diffracted' wavelength of microwaves (much) smaller than size of barrier allow an implied comparison	2
				total =9 marks	

Question number	Answer	Notes	Marks
4(a) (i)	A - amplitude;		1
(ii)	B - frequency;		1
(b) (i)	Any of - e.g. Light, (any named) electromagnetic wave, water waves, S(econdary) seismic waves;	Allow • slinky if described correctly • wave on a string Ignore 'heat waves'	1

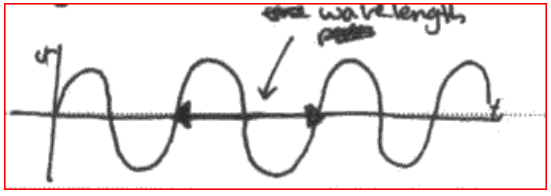
(ii)	Longitudinal - Idea that vibration is parallel to **energy transfer**; e.g. vibration is in the same direction that the **wave travels** they (vibrations) are in the same direction that the **wave moves** Transverse – Idea that vibration is perpendicular to **energy transfer**; e.g. vibration is at 90º to the direction that the **wave travels** they (vibration) are at right angles to the direction the **wave moves**	Ignore left to right, up and down, to and fro, side to side Accept • oscillation for vibration • information transfer for energy transfer • clear labelled diagrams, e.g.  Condone for longitudinal 'particles oscillate in the same direction that the wave goes'	2

(Total for Question 4 = 5 marks)

Question number	Answer	Notes	Marks
5 (a)	B;		1
(b) (i)	MP1. Axes labelled with units; MP2. Correct scales (to occupy at least ¼ of the area of the graph and in sensible intervals); MP3. Plotting; MP4. Plotting; MP5. straight line of best fit which extends beyond given data points;  **Distance in m** / **Time in ms** 0.62 / 1.8 0.80 / 2.4 1.00 / 3.0 1.20 / 3.8 1.38 / 4.2	• ignore orientation of graph • scale intervals on axes should be 2 or 5 or 10 • points should be less than 0.5 sq in diameter • -1 each incorrect plot to max of -2 • tolerance = +/- ½ square • if zero is not included, then line should go through all points except 3rd or 4th • if zero included, look for balance of points	5

(ii)	Attempt to find slope or gradient of line ; AND evaluation of value; matching unit; e.g. = 0.6/0.0018 = 333 m/s	Δ seen or two lines from same axis seen or rise/run seen value in range of 310-350 allow 0.333 km/s 0.333 m/ms	3
(iii)	Any one specific variable from the experiment; e.g. hitting the block in the same place Use the same microphone/timer/wires Ensure there is no 'hammer bounce'	These must be specific to the experiment Accept same • temperature • humidity • density • draughts • force • block ignore • 'keep everything the same' • use control variables • repeat experiment	1
(iv)	Any 2 suggestions from MP1. repeat the time readings (for each distance); MP2. measure the distance to the sensor of the microphone; MP3. use wider range of distance readings (<0.62 or >1.38); MP4. use intermediate distances (between points);	ignore imprecise suggestions e.g. • 'be careful with timer' • 'change the distance'	2

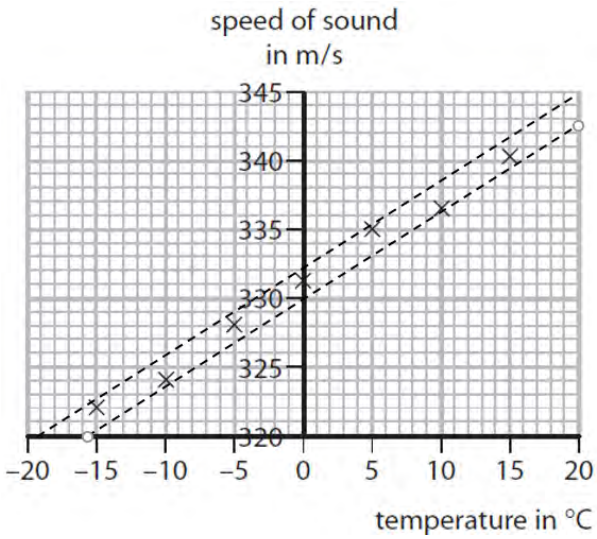
(Total for Question 5 = 12 marks)

Question number	Answer	Notes	Marks
6 (a)	standard definition of wavelength; e. • distance between two points on a wave/ two peaks/ two troughs • distance between each wavefront • distance travelled by wave in one time period 	allow: from clear diagram crest for peak ignore: • 'the length of a wave' • 'distance taken for 1 cycle' • distance between one wave and the next one	1
6 (bi)	Speed of wave = frequency x wavelength;	allow: in any rearrangement $v = f.\lambda$	1
(bii)	substitution into any form of the equation ; evaluation; e. $3(m/s) = 1.5(Hz) \times \lambda$ $(\lambda) = 2(m)$;	 accept for 1 mark $\frac{3}{1.5}$	2

Question number	Answer	Notes	Marks
6 (ci)	Diffraction; And one of • The incoming wave spreads out at the gap; • The energy carried by the wave spreads out ;	allow: • diffraction seen in (cii) • recognisable spelling for 'diffraction' ignore: • the wave gets bigger • wave is bent • (wavefront is) curved	2
6 (cii)	idea that (diffraction only apparent when) λ and size of gap comparable/RA; wavelength of light is very small / smaller than water waves /smaller than the gap;	Allow RA	2
		Total	**8**

Question number	Answer	Accept	Reject	Marks
7 (a) (i)	3;	Three /3.0		1
(ii)	0.002 (s) / 2ms ; 500 (Hz) / 0.5kHz	0.001 ecf only if 2ai=6 correct answer without working for 2 marks 1000 ecf only if 2ai =6		2
(b)	All of waves at smaller amplitude (can vary); All of complete waves at higher frequency (can vary);	Any wave form Accept two diagrams that clearly show the candidate's intention		2

Total 5 marks

Question number	Answer	Notes	Marks
8 (a)	idea that higher frequency gives higher pitch;	allow reverse argument condone idea of proportionality / linearity	1
(b) (i)	(wave) speed = frequency × wavelength	allow abbreviation, e. $v = f \times \lambda$ or rearrangements	1
(ii)	substitution into correctly rearranged equation; evaluation; e. (v =) 340 / 160 (v =) 2.1 (m)	 allow 2.125, 2.12, 2.13 or 2 (if supported)	2
(c) (i)	straight line of best fit drawn within indicated area;  	line does not need to be extended beyond data range for this mark	1
(ii)	line of best fit extended to 20°C; student's own value from graph ± half a square;		2

(d)	any 2 from: MP1. speed (of sound) decreases (with temperature); MP2. frequency is constant; MP3. so wavelength decreases (with temperature);	 allow 'sound slows down' ignore references to particle speed allow λ is smaller	2

Total 9 marks

Question number			Answer	Accept	Reject	Marks
9	(a)	(i)	(Signal has) two values; Only;	On or off, 0 or 1, two signal strengths Binary		2
		(ii)	Any two of The idea of increased frequency (of wave or modulation); The idea of regeneration (allowing more data to arrive); The idea of using increased bandwidth; The idea of using additional (signal) level; The idea of multiplexing (e.g. use more than one channel);	send more bits/sparks, send morse code more quickly, send other letters The response should be about the signal, so ignore: idea of just sending a longer message using optical fibre(s)		2
	(b)	(i)	(wave) speed = frequency x wavelength	$v = f \times \lambda$ (accept rearrangements)		1
		(ii)	Substitution; Calculation; e.g.: 820 000 x 366 = 300 120 000 or 300 000 000 or 3×10^8 (m/s)	Bald answer;; Power of ten error (for 1 mark) e.g. 300 000 m/s Alternative <u>correct</u> units (for 2 marks) e.g. 300 000 km /s		2

Question number			Answer	A	Reject	Marks
9	(c)		183 (m);			1
	(d)		Any three of: MP1 Electrons move OR there is a current Or negative charge moves; MP2 (Discharge) to earth OR across cloud OR to named object – tree, house, lightning conductor; MP3 Air conducts; MP4 Phenomenon e.g. thunder clap / lightning;	Sparks generate radio waves; Lightning causes (radio) interference; Correct reference to electrostatic attraction / repulsion ;		3
					Total	**11**

Question number	Answer	Notes	Marks
10 (a)	D		1
(i) (ii)	C		1
(b)	f = 1/T (NO MARK) f= 1/5; 0.2 (Hz);	Bald 0.2 (Hz) scores 2 marks	2