PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 5: WAVES AND PARTICLE NATURE OF LIGHT

WAVE PROPERTIES AND STATIONARY WAVES

SCORE	PERCENTAGE
/680	%

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Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• use of $v = f\lambda$ (1) • identifies 0.5 m is 5 gaps (1) • v = 360 m s^{-1} (1)	Example of calculation $\frac{\lambda}{2} = \frac{0.50}{5}$ λ = 0.20 m v = 1800 Hz × 0.20 m = 360 m s^{-1}	3

Q2.

Question Number	Answer	Mark
	C	1

Q3.

Question Number	Answer	Mark
	C	1

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
	• states wavelength = 1.2 cm	(1)	Example of calculation: $\lambda = 4.8 \times 0.25$ cm = 1.2 cm	
	• use of E = stress / strain	(1)	$A = \pi d^2 / 4$ $= \pi(3.6 \times 10^{-6}\ m)^2 / 4$ $= 1.012 \times 10^{-11}\ m^2$	
	• use of $A = \pi d^2/4$	(1)	stress = strain × E = $9.7 \times 10^{-9} \times 1.2 \times 10^{9}$ N m^{-2}	
	• use of stress = F/A	(1)	= 11.64 N m^{-2} $T = F$	
	• use of $v = \sqrt{(T/\mu)}$	(1)	= stress × A = 11.64 N m^{-2} × 1.012×10^{-11} m^2 = 1.18×10^{-10} N	
	• use of $v = f\lambda$ with any two of the stated / measured / calculated values of v, f or λ to calculate the other	(1)	$v = \sqrt{(\ \div\ )} = \sqrt{8.92 \times 10^{-3}} =$ 0.094 m s^{-1} Using $v = f\lambda$, v = 7.9 Hz × 0.012 m = 0.0912 m s^{-1}	**7**
	• comparison of this calculated value of v, f or λ with the value obtained another way	(1)	Agree to within 3%, so suggests consistent	

Q5.

Question Number	Answer	Mark
(a)	Lowest / minimum frequency (of light / photons incident on a metal) that will cause electrons to be emitted (from surface) **Or** the frequency of (light / photons) that will cause electrons to be emitted (from the surface of a metal) with zero kinetic energy **(1)** (accept only just emitted)	**1**
(b)	Conversion of eV to J **(1)** Use of $E = hf$ **(1)** $f = 5.5 \times 10^{14}$ Hz **(1)** Example of calculation $\varphi = (2.28\ eV \times 1.6 \times 10^{-19}\ C)$ $= 3.65 \times 10^{-19}$ J $f = 3.65 \times 10^{-19}$ J / 6.63×10^{-34} J s = 5.50×10^{14} Hz	**3**
	Total for Question	**4**

Q6.

Question Number	Answer	Mark
(a)	Change in direction of wave (accept ray or any named wave) (do not accept bend) (1) (Due to) change in (optical) density / speed / medium (1)	2

Question Number	Answer	Mark
(b)	There is no change in direction for the light (passing between the water and the gel) **Or** There is no refraction (as the light passes between the water and the gel) (accept … within the beaker) (1) The light must have the same/similar wave speed in the water and gel (1) (accept same/similar density for water and gel)	2

Q7.

Question Number	Answer	Mark
	C	1

Q8.

Question Number	Answer	Additional Guidance	Mark
	• Use of $f = \frac{1}{T}$ with $T = 125\ \mu s$ (1) • 8000 Hz (1)	Example of calculation $f = \frac{1}{1.25\times10^{-8}\ s} = 8000$ Hz	2

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of $f = 1/T$ (1) • use of $v = f\lambda$ (1) • wavelength = 7.5×10^6 m (1)	MP3: accept variations e.g. 1.75 waves or two wavelengths averaged with correct calculation Example of calculation 2 waves $2T = 0.05$ s $T = 0.025$ s $f = 1/0.025$ s $= 40$ Hz $\lambda = 3.00 \times 10^8$ m s^{-1} ÷ 40 Hz $= 7.5 \times 10^6$ m	3

Q10.

Question Number	Answer	Mark
	D	1

Q11.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Wavelength = 44 cm	(1)		1
(ii)	• Use of $v = \sqrt{\frac{T}{\mu}}$ • Use of $v = f\lambda$ (ecf from (i)) • f = 320 Hz	(1) (1) (1)	Example of calculation $v = \sqrt{\frac{88.6\ \text{N}}{4.47 \times 10{-}3\ \text{kg m}{-}1}}$ = 141 m s^{-1} f = 141 m s^{-1} / 0.44 m = 320 Hz	3

Q12.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• use of strain = extension / length • change in length = 4.8×10^{-18} (m) **Or** max strain for 0.001× proton size = 2.2×10^{-22} • comparison of their change in length to 8.8×10^{-19}(m) **Or** comparison of their max strain to 1.2×10^{-21}	(1) (1) (1)	Example of calculation Change in length = $1.2 \times 10^{-21} \times 4000$ m = 4.8×10^{-18} m Fraction of proton diameter = 4.8×10^{-18} m ÷ 8.8×10^{-16} m = 0.0055	3

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• half wavelength path difference means waves in antiphase	(1)	Do not accept 'out of phase' for MP1	
	• so destructive interference takes place	(1)		
	• this results in zero amplitude, (so no signal detected)	(1)		
	• a change in length will result in a change in path difference, so signal detected **Or** a change in length will result in a change in phase difference, so signal detected	(1)	Accept reference to being 'not out of phase' for MP4	**4**

Question Number	Acceptable answers		Additional guidance	Mark
(iii)	• if initially the path difference is zero there will be a maximum signal	(1)	MP2 alternative: a change from minimum amplitude would represent a much larger percentage (therefore more sensitive)	
	• a change from max amplitude would represent a much smaller percentage (therefore less sensitive)	(1)	MP2 Accept 'it is easier to detect the change from no light to light' MP2 Accept suitable reference to uncertainty	**2**

Q13.

<table>
<tr><th>Question Number</th><th>Acceptable answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>(a)*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5 - 4</td><td>3</td></tr>
<tr><td>3 - 2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.

<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>(6)</td></tr>
</table>

	Indicative content • the progressive waves are reflected and two waves travelling in opposite directions meet • superposition/interference takes place • where the waves are in phase, it is constructive, forming antinodes • where the waves are in antiphase, it is destructive, forming nodes • antinodes are points of maximum amplitude, so water will not remain at antinodes • nodes are points of zero displacement, so water can stay at these points		

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
	• Wave and reflection will meet **(1)** • Superposition / interference occurs **(1)** • Where in antiphase, destructive interference **(1)** • Zero/minimum amplitude at nodes – so mice won't hear **(1)** **Either** • But node separation = ½ wavelength = (about) 7 mm **(1)** • Too small a space for a mouse to avoid the ultrasound, so suggestion not correct **(1)** **Or** (MP5 and 6) • Wall absorbs some ultrasound so reflected wave has smaller amplitude than incident wave **(1)** • Incomplete cancellation, some ultrasound even at nodes, so suggestion (probably) incorrect **(1)** **Or** (MP5 and 6) • Waves also arrive from other walls/floor/ceiling/multiple reflection **(1)** • Complete cancellation unlikely so suggestion (probably) incorrect **(1)** **Or** (MP5 and 6) • A standing wave will only be formed if the length of the room is a whole number of half wavelengths **(1)** • Otherwise there will be no nodes so no silent spots where the mouse won't hear **(1)**	Example of calculation $\lambda/2 = 0.013$ m / 2 = 0.0065 m	6

Q15.

Question Number	Answer	Additional Guidance	Mark
	• Recognises $\lambda = 2L$ (1) • Equates $v=f\lambda$ **and** $v = \sqrt{gh}$ (1) • $T = 5.9 \times 10^4$ s (1)	Example of calculation $T = \frac{L}{\sqrt{gh}} = \frac{2 \times 4.0 \times 10^5 \text{ m}}{\sqrt{9.81 \text{ m s}^{-1} \times 19 \text{ m}}} =$ 5.9×10^4 s = 16.4 h	3

Q16.

Question Number	Answer	Mark
(a)	To be able to distinguish which reflection comes from which emission **Or** so one pulse returns before the next one is emitted (1)	1
(b)	Use of $v = s/t$ (1) Correct use of factor of 2 (double distance or double time) (1) Pulse duration = 2.4×10^{-3} s (0.0024 s, 2.4 ms) (1) Example of calculation Time = 2 × 0.4 m ÷ 330 m s^{-1} Pulse duration = 2.4×10^{-3} s	3
(c)	(Ultrasound) reflected away from the sensor **Or** (Ultrasound) reflected towards the floor (1)	1
	Total for Question	5

Q17.

Question Number	Answer	Additional Guidance	Mark
	• use of $v = f\lambda$ (1) • Path difference needs to be $= \left(n + \frac{1}{2}\right)\lambda$ **Or** Path difference needs to be $\frac{\lambda}{2}$ **Or** Length of chamber needs to be $\frac{\lambda}{4}$ (1) **Or** (1) See $\frac{2.4\text{ m}}{4}$ (1) • (so) waves meet in antiphase • destructive interference	Example of calculation $\lambda = \frac{340\text{ m s}^{-1}}{140\text{ s}^{-1}} = 2.43\text{ m}$ path difference $= 2l = \frac{2.43\text{ m}}{2}$ $l = \frac{2.43\text{ m}}{4} = 0.61\text{ m}$	4

Q18.

Question Number	Answer	Mark
*(a)	**(QWC – Work must be clear and organised in a logical manner using technicalwording where appropriate)** a standing/stationary wave (1) Waves from the generator are reflected at the end **Or** waves are travelling in both directions (1) (When the two) waves (meet they) superpose/undergo superposition (1) Producing points where the waves are in phase and points where they are in antiphase **Or** producing points of zero amplitude and points of maximum amplitude OR producing nodes and antinodes (1)	4
(b)	Wavelength = 2 × 1.8 m (1) Use of speed = wavelength x frequency (1) Speed = 1200 m s^{-1} (1) Example of calculation λ = 2 × 1.8 m v = 330 Hz × 3.6 m v = 1188 m s^{-1}	3
(c)(i)	Point is a node, so zero amplitude OR Point is a node, so string not moving (1) So no energy absorbed **Or** Waves continue to move after superposition (1)	2
(c)(ii)	(Original frequency x 2) = 660 Hz (1)	1
(c)(iii)	Captured twice per cycle = 1320 Hz (allow ecf from (c) (iii)) (1) If more than 1320 Hz will be captured at points other than max amplitude (1)	2
(d)	Scale divisions of 20 Hz **Or** Wide pointer **Or** nominal output (only) (1) Lack of precision (scale related) **Or** Lack of accuracy (output related) (1)	2
	Total for question	14

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Q19.

Question Number	Answer	Mark
	D – Two points $\frac{\lambda}{2}$ apart oscillate with the same amplitude	1
	Incorrect Answers: A – Points on a wave do not all oscillate in phase B – A node is formed from destructive interference C – Stationary waves may also be formed from longitudinal waves	

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• initially the waves are in phase (1) • as one detector moves there is a path difference (1) • they are in antiphase at the point shown because the detector has moved half a wavelength (or an odd multiple) (1)		**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• calculates distance moved by detector = 7.4 cm (1) • use of wavelength = distance / 9 (= 0.822 cm) (1) • use of $v = f\lambda$ (1) • v = 329 m s^{-1} to 2 or 3 sf (1)	<u>Example of calculation</u> Distance moved = 15.4 cm - 8.0 cm = 7.4 cm Wavelength = 7.4 cm / 9 waves = 0.822 cm v = 40 000 Hz × 0.00822 m = 329 m s^{-1}	**(4)**

Question Number	Acceptable Answers		Additional Guidance	Mark
(c)	• the pointer on the dial is about as thick as the interval between the scale markings	(1)		
	• this will cause a large uncertainty in measurements	(1)		
	OR			
	• there is a gap between pointer on the dial and the scale so there can be a parallax error	(1)		
		(1)		
	• this will introduce uncertainty in measurements	(1)		
	OR			
	• the frequency on the dial may differ from the output	(1)		
	• so there could be a <u>systematic</u> error			**(2)**

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	
(i)	• Wear safety glasses (to protect eyes from breaking wire) **Or** wear suitable footwear (to protect feet from falling masses) **Or** place sand tray under masses (to catch them if they fall)		**1**

Question Number	Acceptable Answer		Additional Guidance	
(ii)	• $\lambda = 2L$ substituted into $v = f\lambda$ • v substituted into $v = \sqrt{\frac{T}{\mu}}$ • Correct re-arrangement into $y = mx + c$ format	**(1)** **(1)** **(1)**	$v = f\lambda$ and $\lambda = 2L$ so $v = 2fL$ $v = \sqrt{\frac{T}{\mu}}$, so $4f^2L^2 = \frac{T}{\mu}$ $L^2 = \left(\frac{T}{4\mu}\right).\frac{1}{f^2}$, so gradient is $\frac{T}{4\mu}$	**3**
(iii)	• Gradient calculated • Use of gradient = $\frac{T}{4\mu}$ • $\mu = 1.8$ (g m^{-1}) • SWG consistent with their calculated value of μ (24 swg)	**(1)** **(1)** **(1)** **(1)**	Example of calculation gradient = $\frac{(0.043 - 0)\text{m}^2}{(15.0 - 0.0) \times 10^{-6}\text{s}^2} = 2.87 \times 10^3\text{m}^2\text{s}^{-2}$ $\mu = \frac{2.1\text{ kg} \times 9.81\text{ m s}^{-2}}{4 \times 2.87 \times 10^3\text{m}^2\text{s}^{-2}} = 1.79 \times 10^{-3}\text{ kg m}^{-1}$ $\therefore \mu = 1.79$ g m^{-1}	**4**

Q2.

Question Number	Acceptable Answers		Additional guidance	Mark
	• use of $v = f\lambda$	(1)	Example of calculation $\frac{\lambda}{2} = \frac{0.50}{5}$	
	• identifies 0.5 m is 5 gaps	(1)	$\lambda = 0.20$ m	
	• $v = 360$ m s^{-1}	(1)	$v = 1800$ Hz $\times$ 0.20 m $= 360$ m s^{-1}	3

Q3.

Question Number	Answer	Additional Guidance	Mark
	Use of $E = hf$ **and** $v = f\lambda$ (1) Conversion eV to J (1) $\lambda = 2.9 \times 10^{-7}$ m (1)	Example of calculation $\lambda = \frac{6.63\times10^{-34}\text{J s} \times 3.0\times10^{8}\text{m s}^{-1}}{4.3\text{ eV}\times 1.6\times10^{-19}\text{ C}} = 289$ nm	3

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $L = \lambda/2$ **(1)** • Use of $v = f\lambda$ **(1)** • $f = 180$ Hz **(1)**	Example of calculation: $\lambda = 2 \times 0.45$ m $= 0.90$ m $f = v/\lambda = 160$ m s^{-1}/0.9 m $= 178$ Hz	3

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Calculate missing $f^2 = 9025$ (1) • Plot missing point (1) • Draw line of best fit (1)	Plot (35, 9025) or their calculated value of f^2	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• Determines the gradient (1) • Equates $v = f\lambda$ and $v = \sqrt{\frac{T}{\mu}}$ (1) • Uses $\lambda = 0.8$ (m) (1) • Mass per unit length $\mu = (6.0 \text{ to } 6.2) \times 10^{-3}$ (kg m^{-1}) (1) • Conclusion consistent with their value (1)	e.g. gradient$= \frac{(10200-0)}{(40-0)} = 255$ accept $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ $\mu = \frac{1}{255\text{Hz}^2\text{N}^{-1} \times 0.8^2\text{m}^2} = 6.1 \times 10^{-3}$ (kg m^{-1})	5

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of $f = 1/T$ (1) • use of $v = f\lambda$ (1) • wavelength $= 7.5 \times 10^6$ m (1)	MP3: accept variations e.g. 1.75 waves or two wavelengths averaged with correct calculation Example of calculation 2 waves $2T = 0.05$ s $T = 0.025$ s $f = 1/0.025$ s $= 40$ Hz $\lambda = 3.00 \times 10^8$ m s$^{-1} \div 40$ Hz $= 7.5 \times 10^6$ m	3

Q7.

Question Number	Answer	Mark
	C increasing the length of the string	1
	Incorrect Answers: A results in a higher value for f B results in a higher value for f D results in a higher value for f	

Q8.

Question Number	Answer	Mark
	C	**1**

Q9.

Question Number	Acceptable Answers	Additional Guidance	Mark
	C		**1**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of stress = F/A **(1)** • Use of Young modulus = stress / strain **(1)** • Use of strain = $\Delta x/x$ **(1)** • Extension = 0.053 m **(1)**	Example of calculation stress = 93.4 N / 6.6 $\times 10^{-7}$ m^2 = 1.42 $\times 10^{8}$ N m^{-2} strain = 1.42 $\times 10^{8}$ N m^{-2} / 1.8 $\times 10^{9}$ N m^{-2} = 0.0786 extension = 0.0786 × 0.68 m = 0.053 m	**4**
(ii)	• Increase tension so increase wavespeed since $v = \sqrt{\frac{T}{\mu}}$ **Or** decrease μ so increase wavespeed since $v = \sqrt{\frac{T}{\mu}}$ **(1)** • Since $v = f\lambda$ and wavelength unchanged, this increases frequency **(1)**		**2**

Q11.

Question Number	Answer	Mark
	D – increases non-linearly	**1**
	Incorrect Answers: A – incorrect as $f \propto \sqrt{T}$ B – incorrect as $f \propto \sqrt{T}$ C – incorrect as $f \propto \sqrt{T}$	

Q12.

Question Number	Answer	Mark
	B	1

Q13.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Wavelength = 44 cm	(1)		1
(ii)	• Use of $v = \sqrt{\frac{T}{\mu}}$ • Use of $v = f\lambda$ (ecf from (i)) • f = 320 Hz	(1) (1) (1)	Example of calculation $v = \sqrt{\frac{88.6\ \text{N}}{4.47 \times 10{-}3\ \text{kg m}{-}1}}$ $= 141\ \text{m s}^{-1}$ $f = 141\ \text{m s}^{-1} / 0.44\ \text{m}$ $= 320\ \text{Hz}$	3

Q14.

Question Number	Answer	Mark
(a)	Oscillations/vibrations (of molecules) parallel to direction of propagation (1) **Or** oscillations parallel to direction of wave travel **Or** oscillations parallel to direction of energy transfer Produces compressions and rarefactions (1)	2
(b)	Otherwise there wouldn't be a way of telling which bit of reflected sound originated with which bit of emitted sound **Or** so one returns before one emitted (1)	1
(ci)	time (= 1÷16 Hz) = 0.063 (s) (at least 2 sf) (1)	1
(cii)	Use of factor of 2 (1) Use of $v = s/t$ (1) distance = 48 m (1) (Use of 'show that' value gives 46m) <u>Example of calculation</u> $2 \times$ distance = 1530 m $s^{-1} \times 0.063$ s distance = 48 m	3
(ciii)	A shorter time between clicks because the distance is shorter **Or** more frequent clicks allow rapid motion to be perceived. **Or** allow position to be determined precisely/accurately. (1)	1
(d)	Speed in air lower than speed in water (1) So wavelength in air shorter than wavelength in water **Or** pulse length in air is shorter than pulse length in water **Or** attempt at numerical comparison of wavelength or pulse length (1) So bat echolocation will detect smaller targets **Or** detect smaller differences in position (conditional on MP2) (1) (Accept 'show more detail' or 'better resolution')	3
	Total for question	11

Q15.

Question Number	Answer	Additional guidance	Mark
	B	$(\frac{v_2}{f})$	**(1)**

Q16.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• No of divisions read from oscilloscope trace • Use of time base setting • Use of $f = 1/T$ • Use of $v = f\lambda$ • $v = 340\ \text{m s}^{-1}$	(1) (1) (1) (1) (1)	MP1: Must be for a recognised part of wave Example of calculation $T = 3 \times 0.20 \times 10^{-3}\ \text{s} = 6.0 \times 10^{-4}\ \text{s}$ $f = \frac{1}{6.0 \times 10^{-4}\ \text{s}} = 1.67 \times 10^{3}\ \text{Hz}$ $v = 1.67 \times 10^{3}\ \text{s}^{-1} \times 0.205\ \text{m} = 342\ \text{m s}^{-1}$	5

Q17.

Question number	Acceptable answers	Additional guidance	Mark
	• Sensible estimate of uncertainties from readings given **(1)** • Adds percentage uncertainties **(1)** • Hence calculates uncertainty in speed **(1)** • Candidate's conclusion must be supported by their estimate of the uncertainties **(1)**	Example of calculation: %U in L is (0.1/25.6) x 100 % = 0.4 % %U in F is (1/320) x 100 % = 0.3 % %U in speed is 0.7 % 328 x 0.007 = 2 Speed = 328 ± 2 All three results are within the calculated uncertainty so concludes student B is correct	4

Q18.

Question Number	Answer	Additional Guidance	Mark
	• Recognises $\lambda = 2L$ (1) • Equates $v=f\lambda$ **and** $v=\sqrt{gh}$ (1) • $T = 5.9 \times 10^4$ s (1)	Example of calculation $T = \frac{L}{\sqrt{gh}} = \frac{2 \times 4.0 \times 10^5 \text{ m}}{\sqrt{9.81 \text{ m s}^{-1} \times 19 \text{ m}}} =$ 5.9×10^4 s = 16.4 h	3

Q19.

Question Number	Answer		Mark
(a)	Calculates path difference = 12 (cm) Phase difference 0, 360° or 2π **Or** Calculates number of wavelengths in two paths Phase difference 0, 360° or 2π	(1) (1) (1) (1)	2
(b)	Waves superpose **Or** interference between two waves takes place In phase constructive **Or** Antiphase destructive Links to amplitude maximum **Or** amplitude zero respectively In phase/constructive/max amplitude is where chocolate is hot with opposite at cold spots. **Or** Antiphase/destructive/min amplitude is where chocolate is cold with opposite at hot spots.	(1) (1) (1) (1)	4
(c)	Coherent means a constant phase relationship (If the relationship not constant) a point could sometimes be constructive and sometimes destructive	(1) (1)	2
(d)	Use of $c = f\lambda$ Calculates $c = 2.94 \times 10^8$ (m s^{-1}) **Or** $\lambda = 12.2$ (cm) **Or** $f = 2500$ (MHz) Sensible comment based on their calculated value. e.g. close to real value, so successful **Or** reference to uncertainty in data Example of calculation $c = 2.45 \times 10^9$ Hz × 0.12 m $c = 2.94 \times 10^8$ m s^{-1}	(1) (1) (1)	3
	Total for question		11

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Q20.

Question Number	Answer	Mark
(a)	**When illuminated:** Use of the word <u>photon</u> (1) photons/light cause emission of (photo)electrons (1) Idea that (photo) electrons form a current (1) photon energy greater than or equal to work function. (1) **In darkness:** No photons so no photoelectrons released (1)	5
(b)	Use of $E = hf$ (1) Conversion of eV to J (1) One of the 4 values below correct $f = 5.2 \times 10^{14}$ Hz or $\lambda = 5.8 \times 10^{-7}$ m for caesium $f = 8.8 \times 10^{14}$ Hz or $\lambda = 3.4 \times 10^{-7}$ m for zinc (1) Comment that Cs is in the visible range or Zn is ultraviolet – allow even without supporting calculation (1) **Alternative method** Allow assumed max freq/min wavelength for visible light then, calculation of work function, quoted in eV, comparison with given work functions, conclusion: Use of (1); work fn (1), in eV (1), comparison (1) <u>Example of calculation</u> $f = \varphi \div h = (2.14 \times 1.6 \times 10^{-19})$ J $\div 6.63 \times 10^{-34}$ J s $= 5.2 \times 10^{14}$ Hz for caesium $f = \varphi \div h = (3.63 \times 1.6 \times 10^{-19})$ J $\div 6.63 \times 10^{-34}$ J s $= 8.8 \times 10^{14}$ Hz for zinc	4
(ci)	Maximum displacement of the wave **Or** maximum displacement from the mean **Or** maximum displacement from equilibrium (1)	1
(cii)	**Max 3** Size of the gap (in the soundtrack) determines the amount of light (1) Amount of light determines number of photons (1) Number of photons determines number of (photo) electrons (released by phototube) (1) Number of electrons determines size of current (in the circuit) (1) (Combining MP 1 and 2 by writing "size of the gap determines number of photons" scores 1 mark. Combining MP 2 and 3 by writing "the amount of light determines number of (photo) electrons" also scores 1 mark)	3
	Total for question	13

Q21.

Question Number	Acceptable answers	Additional guidance	Mark
(a)(i)	• Use of $\lambda = h/p$ and $v = f\lambda$ (1) • Momentum of photon = 3.3×10^{-27} (N s) (1)	Example of calculation Momentum of photon = $p = hf/c$ $= 6.63 \times 10^{-34}$ J s $\times 1.5 \times 10^{15}$ Hz $\div 3.00 \times 10^{8}$ m s^{-1} $= 3.315 \times 10^{-27}$ N s	2

Question Number	Acceptable answers	Additional guidance	Mark
(a)(ii)	• Momentum transfer = 6.6×10^{-27} (N s) (1)	Ecf momentum from (i) in parts (a)(ii) and (c)	1

Question Number	Acceptable answers	Additional guidance	Mark
(b)(i)	• Use of $hf = \varphi + ½ mv^2_{max}$ (1) • Use of $E_K = ½ mv^2$ (1) • $v = 8.4 \times 10^5$ (m s^{-1}) (1)	Example of calculation $hf = \varphi + ½ mv^2_{max}$ $hf = 6.63 \times 10^{-34}$ J s $\times 1.5 \times 10^{15}$ Hz $= 9.95 \times 10^{-19}$ J $hf - \varphi = 9.95 \times 10^{-19}$ J $- 6.7 \times 10^{-19}$ J $= 3.25 \times 10^{-19}$ J 3.25×10^{-19} J $= ½ \times 9.11 \times 10^{-31}$ kg $\times v^2$ $v = 8.4 \times 10^5$ m s^{-1}	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)(ii)	• Use of $p = mv$ (1) • Momentum of photoelectron = 7.7×10^{-25} N s (1)	Example of calculation $p = 9.11 \times 10^{-31}$ kg $\times 8.4 \times 10^5$ m s^{-1} Momentum of photoelectron = 7.68×10^{-25} N s MP2: Using show that value $p = 7.3 \times 10^{-25}$ N s	2

Question Number	Acceptable answers	Additional guidance	Mark
(c)	An explanation that refers to the following points: • the change in momentum of the graphene oxide is the same as the change in momentum of the photoelectron (1) • so the (change in) momentum is much larger for the photoelectron than for the reflected photon (1)	Accept converse statement and answer that is consistent with candidate's values in (a) and (b)	2

Q22.

Question Number	Answer		Mark
(a)	Quantum of … **Or** (discrete) packet of … **Or** discrete quantity of …	**(1)**	
	(To score the mark must refer to something relevant e.g. light / energy) Of <u>electromagnetic</u> radiation/energy	**(1)**	**2**
*** (b)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)	**(1)**	
	describe relevant interaction between single photon and single electron		
	photon energy depends on frequency **Or** reference to $E = hf$ (must be link to photons/light)	**(1)**	
	if photon energy greater than work function, electron emitted (immediately)	**(1)**	
	whereas for waves energy could build up **Or** with waves that the electron can absorb energy continuously or over time so any frequency should work **Or** but this build up doesn't happen	**(1)**	**5**
(c)(i)	Use of $4.3 \times 1.6 \times 10^{-19}$	**(1)**	
		(1)	
	Use of $E = hf$ $f = 1.0 \times 10^{15}$ Hz	**(1)**	**3**
	<u>Example of calculation</u> $E = 4.3\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}$ $= 6.9 \times 10^{-19}\ \text{J}$ $6.9 \times 10^{-19}\ \text{J} = 6.63 \times 10^{-34}\ \text{Js} \times f$ $f = 1.0 \times 10^{15}$ Hz		
(c)(ii)	Ultraviolet Accept ultraviolet even if frequency in c(i) is incorrect, but allow ecf from candidate's value of frequency to appropriate part of electromagnetic spectrum	**(1)**	**1**
	Total for question		**11**

Q23.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Use of $E = \frac{1}{2}mv^2$ (1) • Use of $E = hf$ **and** $c = f\lambda$ (1) • $\lambda = (2.4 - 2.5) \times 10^{-7}$ (m) (1) • leading to a conclusion that radiation is ultraviolet **Or** conclusion consistent with their value for wavelength (1)	MP4 dependent on MP2 Example of Calculation $\Delta E_k = \frac{1}{2} \times 9.11 \times 10^{-31}\ \text{kg} \times ((2.5 \times 10^6\ \text{m s}^{-1})^2 - (2.1 \times 10^6\ \text{m s}^{-1})^2)$ $\Delta E_k = 8.4 \times 10^{-19}$ (J) $\lambda = \frac{6.63 \times 10^{-34}\ \text{J s} \times 3 \times 10^8\ \text{m s}^{-1}}{8.4 \times 10^{-19}\ \text{J}}$ $\lambda = 2.4 \times 10^{-7}$ (m)	4

Q24.

Question Number	Answer	Mark
(a)	Force (or acceleration): • proportional to displacement from equilibrium/undisplaced/rest position (1) • always acting towards the equilibrium/undisplaced/rest position **Or** always in the opposite direction to the displacement (1)	2
(b)(i)	Acceleration is a maximum at an extreme position (towards X) (1) Acceleration decreases to zero at X (1)	2
(b)(ii)	**Max 3** Total energy remains constant (1) (Elastic) potential energy is transferred to kinetic energy as string moves towards X (1) Kinetic energy is zero at an extreme position and a maximum at X (1) (Elastic) potential energy is a maximum at an extreme position and a minimum at X (1)	3
(c)	Use of $\lambda = 2l$ (1) Use of $v = f\lambda$ (1) $f = 250$ Hz (1) Example of calculation: $\lambda = 2 \times 0.53\ \text{m} = 1.06\ \text{m}$ $f = v/\lambda = 270\ \text{m s}^{-1}/1.06\ \text{m} = 254.7$ Hz	3
	Total for question	10

Q25.

Question Number	Acceptable Answers		Additional guidance	Mark
(i)	• Amplitude/energy/intensity of the soundwave reduces with distance travelled • Appreciate that at A **or** B two waves are interfering destructively **Or** at A **and** B there are nodes • at B the waves have travelled similar distances so have similar amplitudes	(1) (1) (1)	Assume they are talking about point B unless stated otherwise For MP3 Accept answers with respect to waves at point A having different amplitudes due to different distances	3

Question Number	Acceptable Answers		Additional guidance	Mark
(ii)	• Uses graph to identify $\lambda =$ 0.16 (m) • Use of $v = f\lambda$ with a valid value from the graph • v =320 m s^{-1}	(1) (1) (1)	using $\lambda = 0.08$ gives v= 160 m s^{-1} MP2 only Example of Calculation $v = 2000$ Hz $\times$ 0.16 m = 320 m s^{-1}	3

Q26.

Question Number	Answer		Mark
(a)	(sound waves travel as) longitudinal waves **Or** (Air molecules) vibrate parallel to direction of travel of wave	(1)	
	(sound waves travel as) a series of compressions **and** rarefactions **Or** (sound waves travel as) areas of high and low pressure	(1)	
	The idea that these vibrations create a pressure/force/stress/strain on the film **Or** The idea that these compressions/rarefactions create a pressure/force/stress/strain on the film	(1)	
	This pressure/force/stress/strain generates a potential difference (accept idea that vibration/pressure/force/stress/strain causes redistribution of charge within crystal)	(1)	**4**
(b)	Thin film is flexible / lightweight	(1)	
	The idea that there is not much energy in sound	(1)	
	Large area gathers more sound (energy) **Or** Large area generates more power/current/pd	(1)	**3**
(c)	Use of $P=E/t$ with any time, energy in J or kJ Conversion of kJ→J **and** correct time in s (36000 s) P =0.56 W (accept J s^{-1})	(1) (1) (1)	**3**
	<u>Example of calculation</u> Power = 20000 J / 10 × 3600 s Power = 0.56 W		
(d)	**ONE** *Disadvantage* Expensive, Not washable Only works with (loud) noise Long time to charge a phone Low output power	(1)	
	ONE *Advantage* Free source of energy Lower/zero running cost Portable Can be used when away from mains electricity	(1)	**2**
	[Credit should be given for any reasonable correct physics point but not for generalised comments such as 'good for the planet' 'environmentally friendly']		

Q27.

Question Number	Answer	Additional Guidance	Mark
	• use of $v = f\lambda$ (1) • Path difference needs to be $= \left(n + \frac{1}{2}\right)\lambda$ **Or** Path difference needs to be $\frac{\lambda}{2}$ **Or** Length of chamber needs to be $\frac{\lambda}{4}$ (1) **Or** (1) See $\frac{2.4\text{ m}}{4}$ (1) • (so) waves meet in antiphase • destructive interference	Example of calculation $\lambda = \frac{340\text{ m s}^{-1}}{140\text{ s}^{-1}} = 2.43\text{ m}$ path difference $= 2l = \frac{2.43\text{ m}}{2}$ $l = \frac{2.43\text{ m}}{4} = 0.61\text{ m}$	4

Q28.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• A standing wave is set up in the tube **Or** interference (of sound waves) takes place in the tube (1) • Where constructive interference occurs the amplitude is a maximum **Or** at antinodes the amplitude is a maximum (1) • Where destructive interference occurs the amplitude is a minimum **Or** at nodes the amplitude is zero/minimum (1) • Sand is displaced from points of max amplitude to points of min amplitude **Or** sand is displaced from antinodes to nodes (1)		4
(ii)	• Measure over at least 3 heaps (1) • Divide by the number of gaps between the heaps (1) • Repeat measurement and calculate average (1)	i.e at least 2 gaps	3

(iii)	• Use of $d = \frac{\lambda}{2}$ (1) • Use of $v = f\lambda$ (1) • v = 330 (m s^{-1}) and a comment on consistency with 340 m s^{-1} (1)	Example of calculation: $\lambda = 2d = 2 \times 5.1 \times 10^{-2}$ m = 0.102 m $v = 3.25 \times 10^{3}$ Hz × 0.102 m = 332 m s^{-1}	3

Q29.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Use of node to node distance = $\frac{\lambda}{2}$ (1) • Use of $v=f\lambda$ (1) • v = 340 m s^{-1} (1)	Example of Calculation λ = 2 x 0.86 m = 1.72 m v = 200 s^{-1} x 1.72 m = 344 m s^{-1}	3
(ii)	• Wavelength is 1.7 m which is the same order of magnitude as 2 m (1) • Diffraction will take place so sound will be heard at Y (1)	Example of Calculation λ = 2 x 0.86 (m) = 1.7 m	2

Q30.

Question Number	Answer	Mark
	B - $v = 2fl$	1
	Incorrect Answers: A – wavelength is $2l$ C - wavelength is $2l$ D - wavelength is $2l$	

Mark Scheme

Q1.

Question Number	Acceptable Answers		Additional guidance	Mark
(a)	• Sound travels as a longitudinal wave **Or** in a series of compressions **and** rarefactions • With oscillations/vibrations of (air) particles/molecules parallel to the direction of energy transfer	(1) (1)	Accept: Direction of energy transfer **Or** propagation of the wave **Or** direction of wave travel/motion	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(i)	• the idea that there is a wide variation in the first two readings	(1)		1

Question Number	Acceptable Answers	Additional guidance	Mark
(b)(ii)	• uses $\frac{\text{half the range of values}}{\text{mean value}}$ (1) • percentage uncertainty = 8.5% (1)	Example of Calculation $\frac{0.5 \times (0.51\ s - 0.43\ s)}{0.47\ s} \times 100\% = 8.5\%$ Accept calculations based on $\frac{\text{range of values}}{\text{mean value}}$ (17%)	2

Question Number	Acceptable Answers	Additional guidance	Mark
(b)(iii)	• attempt to calculate Δv (1) • $\Delta v = 7.4\ \text{m s}^{-1}$ or $8.0\ \text{m s}^{-1}$ (1)	Example of Calculation $\frac{160\ \text{m}}{0.46\ \text{s}} - \frac{160\ \text{m}}{0.47\ \text{s}} = 7.4\ \text{m s}^{-1}$ Use of 80 m (Δv =3.7) scores MP1 only	2

Question Number	Acceptable Answers	Additional guidance	Mark
(b)(iv)	**Max 2:** • insufficient number of results (1) • identifies one other variable to take into account (1) • difference (in t or v) could be due to human reaction times (1) • uncertainty in results may account for the difference	Do not accept take readings over more days MP2 examples:wind speed/direction, humidity, air pressure MP3 do not credit human error	2

Q2.

Question Number	Answer		Mark
(a)	Resistivity is a property of a material **Or** is constant for a material	(1)	
	Resistance is a property of a wire/component/object **Or** Resistance depends on dimensions of a wire/component/object	(1)	2
* (b)	*Circuit diagram* Wire and a power supply (accept resistor symbol for wire) Ammeter in series and voltmeter in parallel with wire (an Ohmmeter across a wire with no supply scores 2 marks, an Ohmmeter across a wire with a supply scores 0 marks.) (QWC- Work must be clear and organised in a logical manner using technical wording where appropriate.) *Quantities measured* Current and potential difference **Or** resistance (consistent with diagram) Length of wire Diameter/thickness of wire (not area or radius) *Graph* Graph of R against l **Or** graph of V against l (for constant I) **Or** Graph of R against l/A **Or** Graph of RA against l (this mark is only awarded for a graph including different values of length) *Determination of resistivity* Determine the gradient of a relevant graph (allow for a graph of V against I) $A = \pi d^2/4$ **Or** $A = \pi r^2$ Correct processing to find ρ consistent with the graph (if no gradient, award final mark for statement that $\rho=RA/l$, ρ must be the subject)	(1) (1) (1) (1) (1) (1) (1) (1) (1)	9

Q3.

Question Number	Answer		Mark
	Oscillations/vibrations of (air) particles/molecules/atoms	(1)	
	Oscillations/vibrations/displacement parallel to direction of propagation **Or** Oscillations/vibrations/displacement parallel to direction of energy transfer	(1)	
	(Producing) compressions and rarefactions **Or** regions of high and low pressure **Or** it is a longitudinal wave	(1)	3
	Total for question		3

Q4.

Question Number	Answer	Mark
	B	1

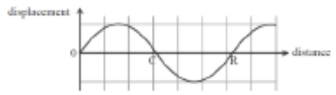
Q5.

Question Number	Answer		Mark
(a)	Particles/atoms/ions/molecules (in metal) oscillate/vibrate	(1)	
	Along direction of propagation **Or** parallel to direction of wave travel **Or** in direction of energy transfer (along direction of motion/movement is insufficient)	(1)	
	Making compressions and rarefactions **Or** as a longitudinal wave	(1)	3
(b)	Use of $s = vt$	(1)	
	Correct application of factor of 2	(1)	
	Answer, $s = 0.015$ m **Or** total journey time for thickness 4 cm = 1.4×10^{-5} s	(1)	
	Comparison – Steel is corroded because thickness less than 4 cm (allow even if no division by 2) **Or** Steel is corroded because detected time less than for 4 cm (allow even if no division by 2)	(1)	4
	(For third mark, accept $s = 0.030$ m where final comparison is with total uncorroded journey distance, 8 cm **Or** time = 6.8×10^{-6} s where final comparison is with half of corroded journey time 2.6×10^{-6} s)		
	Example of calculation $s = 5900 \text{ m s}^{-1} \times 5.1 \times 10^{-6}$ s = 0.030 m Thickness = 0.030 / 2 = 0.015 m		
(c)	Need to measure time at which the echo arrives back **Or** need to measure time taken for echo to return	(1)	
	If continuous couldn't tell when this was **Or** so pulse must return before next is emitted	(1)	
	Shorter pulses means smaller thickness can be measured **Or** longer pulses means only larger thickness can be measured	(1)	3
	Total for question		10

Q6.

Question Number	Answer	Mark
	C	1

Q7.

Question Number	Answer	Mark
	B  	1
	Incorrect Answers: **A** compression and rarefaction both occur at regions of 0 displacement **C** compression and rarefaction both occur at regions of 0 displacement **D** compression and rarefaction are labelled the wrong way round with respect to the direction of the positive displacement	

Q8.

Question Number	Answer	Additional Guidance	Mark
	• Longitudinal wave **Or** Oscillations of air molecules are parallel to the direction of the energy transfer (1) • Creating compressions **and** rarefactions **Or** Creating regions where the molecules are close together **and** regions where they are further apart (1) • Molecules close together create higher pressure **Or** molecules further apart create lower pressure **Or** compressions are areas of high pressure **Or** rarefactions are areas of low pressure (1)		3

Q9.

Question Number	Answer	Mark
	B	1

Q10.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• A standing wave is set up in the tube **Or** interference (of sound waves) takes place in the tube	(1)		4
	• Where constructive interference occurs the amplitude is a maximum **Or** at antinodes the amplitude is a maximum	(1)		
	• Where destructive interference occurs the amplitude is a minimum **Or** at nodes the amplitude is zero/minimum	(1)		
	• Sand is displaced from points of max amplitude to points of min amplitude **Or** sand is displaced from antinodes to nodes	(1)		
(ii)	• Measure over at least 3 heaps	(1)		3
	• Divide by the number of gaps between the heaps	(1)	i.e at least 2 gaps	
	• Repeat measurement and calculate average	(1)		
(iii)	• Use of $d = \frac{\lambda}{2}$	(1)		3
	• Use of $v = f\lambda$	(1)	Example of calculation: $\lambda = 2d = 2 \times 5.1 \times 10^{-2}$ m $= 0.102$ m $v = 3.25 \times 10^{3}$ Hz $\times$ 0.102 m $= 332$ m s^{-1}	
	• v = 330 (m s^{-1}) and a comment on consistency with 340 m s^{-1}	(1)		

Mark Scheme

Q1.

Question Number	Answer	Mark
	C	1

Q2.

Question Number	Answer	Mark
	C	1

Q3.

Question Number	Answer	Additional Guidance	Mark
	• Use of $f = \frac{1}{T}$ with $T = 125\ \mu s$ (1) • 8000 Hz (1)	Example of calculation $f = \frac{1}{1.25\times10^{-8}\ s} = 8000$ Hz	2

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of $f = 1/T$ (1) • use of $v = f\lambda$ (1) • wavelength = 7.5×10^6 m (1)	MP3: accept variations e.g. 1.75 waves or two wavelengths averaged with correct calculation Example of calculation 2 waves $2T = 0.05$ s $T = 0.025$ s $f = 1/0.025$ s $= 40$ Hz $\lambda = 3.00 \times 10^8$ m s^{-1} ÷ 40 Hz $= 7.5 \times 10^6$ m	3

Q5.

Question Number	Answer	Mark
	D wavelength	1
	Incorrect Answers: **A** – determined from the maximum displacement on y-axis **B** – determined from 1/time for one cycle **C** – determined from the time for one cycle on x-axis	

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Wavelength = 44 cm	(1)		1
(ii)	• Use of $v = \sqrt{\frac{T}{\mu}}$ • Use of $v = f\lambda$ (ecf from (i)) • f = 320 Hz	(1) (1) (1)	Example of calculation $v = \sqrt{\frac{88.6\ \text{N}}{4.47 \times 10{-}3\ \text{kg m}{-}1}}$ $= 141\ \text{m s}^{-1}$ $f = 141\ \text{m s}^{-1} / 0.44\ \text{m}$ $= 320\ \text{Hz}$	3

Q7.

Question Number	Answer	Mark
	C	1

Q8.

Question Number	Answer	Mark
	D – both are moving up Incorrect Answers: A – incorrect answer B – incorrect answer C – incorrect answer	1

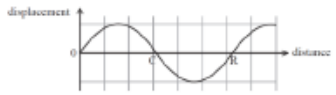
Q9.

Question Number	Answer	Mark
	C	**1**

Q10.

Question Number	Answer	Mark
	D	1

Q11.

Question Number	Answer	Mark
	B  	**1**
	Incorrect Answers: **A** compression and rarefaction both occur at regions of 0 displacement **C** compression and rarefaction both occur at regions of 0 displacement **D** compression and rarefaction are labelled the wrong way round with respect to the direction of the positive displacement	

Q12.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Amplitude/energy/intensity of the soundwave reduces with distance travelled **(1)** • Appreciate that at A **or** B two waves are interfering destructively **(1)** **Or** at A **and** B there are nodes • at B the waves have travelled similar distances so have similar amplitudes **(1)**	Assume they are talking about point B unless stated otherwise For MP3 Accept answers with respect to waves at point A having different amplitudes due to different distances	**3**

Question Number	Acceptable Answers	Additional guidance	Mark
(ii)	• Uses graph to identify $\lambda =$ 0.16 (m) **(1)** • Use of $v = f\lambda$ with a valid value from the graph **(1)** • v =320 m s^{-1} **(1)**	using $\lambda = 0.08$ gives v= 160 m s^{-1} MP2 only Example of Calculation $v = 2000$ Hz $\times$ 0.16 m = 320 m s^{-1}	**3**

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Q13.

Question Number	Acceptable Answers		Additional guidance	Mark
(i)	• Use of node to node distance $= \frac{\lambda}{2}$ • Use of $v = f\lambda$ • $v = 340$ m s^{-1}	(1) (1) (1)	Example of Calculation $\lambda = 2 \times 0.86$ m $= 1.72$ m $v = 200$ s^{-1} x 1.72 m $= 344$ m s^{-1}	3
(ii)	• Wavelength is 1.7 m which is the same order of magnitude as 2 m • Diffraction will take place so sound will be heard at Y	(1) (1)	Example of Calculation $\lambda = 2 \times 0.86$ (m) $= 1.7$ m	2

Q14.

Question Number	Answer	Mark
	The only correct answer is C because decreasing the mass on the hanger decreases the tension in the string and, since $v = \sqrt{\frac{T}{\mu}}$, decreases the speed of waves on the string. $\lambda = v/f$ so the wavelength is shorter and a whole wavelength could fit in the original length A the wavelength at the original frequency is unchanged, so decreasing the length will not allow a whole wavelength B decreasing the frequency will increase the wavelength, since wave speed is unchanged, so this will not allow a whole wavelength D since $v = \sqrt{\frac{T}{\mu}}$, decreasing the mass per unit length will increase the wave speed, increasing the wavelength at the original frequency, so this will not allow a whole wavelength	1

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• initially the waves are in phase (1) • as one detector moves there is a path difference (1) • they are in antiphase at the point shown because the detector has moved half a wavelength (or an odd multiple) (1)		**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• calculates distance moved by detector = 7.4 cm (1) • use of wavelength = distance / 9 (= 0.822 cm) (1) • use of $v = f\lambda$ (1) • v = 329 m s^{-1} to 2 or 3 sf (1)	<u>Example of calculation</u> Distance moved = 15.4 cm - 8.0 cm = 7.4 cm Wavelength = 7.4 cm / 9 waves = 0.822 cm v = 40 000 Hz × 0.00822 m = 329 m s^{-1}	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• the pointer on the dial is about as thick as the interval between the scale markings (1) • this will cause a large uncertainty in measurements (1) <u>OR</u> • there is a gap between pointer on the dial and the scale so there can be a parallax error (1) • this will introduce uncertainty in measurements (1) <u>OR</u> • the frequency on the dial may differ from the output (1) • so there could be a <u>systematic</u> error		**(2)**

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	
	• Waves are reflected from the opposite bridge **(1)** • Waves meet in phase (at mid-point of wire) and superpose **(1)** • Constructive interference occurs giving a maximum displacement **(1)**		**3**

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
*	This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative points seen in answer / Number of marks awarded for indicative points 6 / 4 5-4 / 3 3-2 / 2 1 / 1 0 / 0 **Indicative Content** • Two waves travelling in opposite directions (1) • Superpose / interfere (1) • Constructive (interference) if waves in phase **Or** Constructive (interference) if path difference = $n\lambda$ (1) • Destructive (interference) if waves in antiphase **Or** destructive (interference) if path difference = $(n + ½)\lambda$ (1) • Nodes are formed from points of destructive (interference) **or** antinodes are formed from points of constructive (interference) (1) • Nodes are points with min amplitude **and** antinodes are points with max amplitude (1)		**6**

Q3.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Use of $\lambda = \frac{h}{p}$ (1) • recognise $\lambda = 2 \times$ diameter of atom (1) • 1.7×10^{-24} kg m s^{-1} (1)	Example of calculation $p = \frac{6.63\times10^{-34}\ (\text{J s})}{2\times 2.0\times10^{-10}\ (\text{m})} = 1.67\times 10^{-24}$ kg m s^{-1}	3
(ii)	• A discrete number of half wavelengths fit into the diameter of an atom (1) • Reference to $E = \frac{hc}{\lambda}$ to link wavelength to discrete energy levels (1)		2

Q4.

Question Number	Acceptable Answers	Additional guidance	Mark
	• use of $v = f\lambda$ (1) • identifies 0.5 m is 5 gaps (1) • v = 360 m s^{-1} (1)	Example of calculation $\frac{\lambda}{2} = \frac{0.50}{5}$ λ = 0.20 m v = 1800 Hz × 0.20 m = 360 m s^{-1}	3

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $L = \lambda/2$ **(1)** • Use of $v = f\lambda$ **(1)** • f = 180 Hz **(1)**	Example of calculation: $\lambda = 2 \times 0.45$ m = 0.90 m $f = v/\lambda$ = 160 m s^{-1}/0.9 m = 178 Hz	3

Q6.

Question Number	Answer	Mark
	C	1

Q7.

Question Number	Answer	Mark
	C	1

Q8.

<table>
<tr><th>Question Number</th><th>Acceptable answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>(a)*</td>
<td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

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<tr><td>0</td><td>0</td></tr>
</table>
</td>
<td>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td></td>
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</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

(6)

Indicative content

- the progressive waves are reflected and two waves travelling in opposite directions meet
- superposition/interference takes place
- where the waves are in phase, it is constructive, forming antinodes
- where the waves are in antiphase, it is destructive, forming nodes
- antinodes are points of maximum amplitude, so water will not remain at antinodes
- nodes are points of zero displacement, so water can stay at these points

Q9.

Question Number	Answers	Additional Guidance	Mark
	D	particles undergo no disturbance at an antinode	**(1)**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Wave and reflection will meet (1) • Superposition / interference occurs (1) • Where in antiphase, destructive interference (1) • Zero/minimum amplitude at nodes – so mice won't hear (1) **Either** • But node separation = ½ wavelength = (about) 7 mm (1) • Too small a space for a mouse to avoid the ultrasound, so suggestion not correct (1) **Or** (MP5 and 6) • Wall absorbs some ultrasound so reflected wave has smaller amplitude than incident wave (1) • Incomplete cancellation, some ultrasound even at nodes, so suggestion (probably) incorrect (1) **Or** (MP5 and 6) • Waves also arrive from other walls/floor/ceiling/multiple reflection (1) • Complete cancellation unlikely so suggestion (probably) incorrect (1) **Or** (MP5 and 6) • A standing wave will only be formed if the length of the room is a whole number of half wavelengths (1) • Otherwise there will be no nodes so no silent spots where the mouse won't hear (1)	Example of calculation $\lambda/2 = 0.013\ \text{m} / 2$ $= 0.0065\ \text{m}$	6

Q11.

Question Number	Answer	Additional Guidance	Mark
	• Recognises $\lambda = 2L$ (1) • Equates $v = f\lambda$ **and** $v = \sqrt{gh}$ (1) • $T = 5.9 \times 10^4$ s (1)	Example of calculation $T = \frac{L}{\sqrt{gh}} = \frac{2 \times 4.0 \times 10^5\ \text{m}}{\sqrt{9.81\ \text{m s}^{-1} \times 19\ \text{m}}} =$ $5.9 \times 10^4\ \text{s} = 16.4\ \text{h}$	3

Q12.

Question Number	Answer		Mark
(a)	Calculates path difference = 12 (cm) Phase difference 0, 360° or 2π **Or** Calculates number of wavelengths in two paths Phase difference 0, 360° or 2π	(1) (1) (1) (1)	2
(b)	Waves superpose **Or** interference between two waves takes place In phase constructive **Or** Antiphase destructive Links to <u>amplitude</u> maximum **Or** <u>amplitude</u> zero respectively In phase/constructive/max amplitude is where chocolate is hot with opposite at cold spots. **Or** Antiphase/destructive/min amplitude is where chocolate is cold with opposite at hot spots.	(1) (1) (1) (1)	4
(c)	Coherent means a constant phase relationship (If the relationship not constant) a point could sometimes be constructive and sometimes destructive	(1) (1)	2
(d)	Use of $c = f\lambda$ Calculates $c = 2.94 \times 10^8$ (m s^{-1}) **Or** $\lambda = 12.2$ (cm) **Or** $f = 2500$ (MHz) Sensible comment based on their calculated value. e.g. close to real value, so successful **Or** reference to uncertainty in data <u>Example of calculation</u> $c = 2.45 \times 10^9$ Hz $\times$ 0.12 m $c = 2.94 \times 10^8$ m s^{-1}	(1) (1) (1)	3
	Total for question		11

Q13.

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table></td><td>Guidance on how the mark scheme should be applied:
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</table>

Question Number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • Sound waves incident upon surfaces within the concert hall will be reflected. • Some frequencies will arrive from different directions with a phase difference of (any odd multiple of) π radians **(1) OR** path difference is odd number of half wavelengths • Destructive superposition/interference will occur, causing the waves with those frequencies to be quieter than others. • Other frequencies arrive with a phase difference of zero or (any multiple of) 2π radians **(1) OR** a whole number of wavelengths • Constructive superposition/interference will occur, causing waves with those frequencies to be louder than others. • Problem arises due to reflections from walls, so use absorbing material on surfaces to reduce reflections.		**6**

Question Number	Acceptable answers	Additional guidance	Mark
* (continued)	**Alternative approach based on standing waves:** • Sound waves incident upon surfaces within the concert hall will be reflected. • Reflections from walls set up standing waves (in room) • Nodes and antinodes are formed for certain frequencies of sound • Nodes are areas of zero/low amplitude so the frequencies of those sound waves will be quieter than others • Antinodes are areas of maximum amplitude so the frequencies of these sound waves will be louder than others • Problem arises due to reflections from walls, so use absorbing material on surfaces to reduce reflections		

Q14.

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Question Number	Answer	Mark
(a)	Force (or acceleration): • proportional to displacement from equilibrium/undisplaced/rest position (1) • always acting towards the equilibrium/undisplaced/rest position **Or** always in the opposite direction to the displacement (1)	2
(b)(i)	Acceleration is a maximum at an extreme position (towards X) (1) Acceleration decreases to zero at X (1)	2
(b)(ii)	**Max 3** Total energy remains constant (1) (Elastic) potential energy is transferred to kinetic energy as string moves towards X (1) Kinetic energy is zero at an extreme position and a maximum at X (1) (Elastic) potential energy is a maximum at an extreme position and a minimum at X (1)	3
(c)	Use of $\lambda = 2l$ (1) Use of $v = f\lambda$ (1) $f = 250$ Hz (1) <u>Example of calculation:</u> $\lambda = 2 \times 0.53\ m = 1.06\ m$ $f = v/\lambda = 270\ m\ s^{-1}/1.06\ m = 254.7\ Hz$	3
	Total for question	10

Q15.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Amplitude/energy/intensity of the soundwave reduces with distance travelled (1) • Appreciate that at A **or** B two waves are interfering destructively **Or** at A **and** B there are nodes (1) • at B the waves have travelled similar distances so have similar amplitudes (1)	Assume they are talking about point B unless stated otherwise For MP3 Accept answers with respect to waves at point A having different amplitudes due to different distances	3

Question Number	Acceptable Answers	Additional guidance	Mark
(ii)	• Uses graph to identify $\lambda =$ 0.16 (m) (1) • Use of $v = f\lambda$ with a valid value from the graph (1) • $v = 320\ m\ s^{-1}$ (1)	using $\lambda = 0.08$ gives $v = 160\ m\ s^{-1}$ MP2 only <u>Example of Calculation</u> $v = 2000\ Hz \times 0.16\ m = 320\ m\ s^{-1}$	3

Q16.

Question Number	Answer	Mark
	B	1

Q17.

Question Number	Answer		Mark
(a)	(sound waves travel as) longitudinal waves **Or** (Air molecules) vibrate parallel to direction of travel of wave	(1)	
	(sound waves travel as) a series of compressions **and** rarefactions **Or** (sound waves travel as) areas of high and low pressure	(1)	
	The idea that these vibrations create a pressure/force/stress/strain on the film **Or** The idea that these compressions/rarefactions create a pressure/force/stress/strain on the film	(1)	
	This pressure/force/stress/strain generates a potential difference (accept idea that vibration/pressure/force/stress/strain causes redistribution of charge within crystal)	(1)	4
(b)	Thin film is flexible / lightweight	(1)	
	The idea that there is not much energy in sound	(1)	
	Large area gathers more sound (energy) **Or** Large area generates more power/current/pd	(1)	3
(c)	Use of $P=E/t$ with any time, energy in J or kJ Conversion of kJ→J **and** correct time in s (36000 s) P =0.56 W (accept J s^{-1}) <u>Example of calculation</u> Power = 20000 J / 10 × 3600 s Power = 0.56 W	(1) (1) (1)	3
(d)	**ONE** *Disadvantage* Expensive, Not washable Only works with (loud) noise Long time to charge a phone Low output power	(1)	
	ONE *Advantage* Free source of energy Lower/zero running cost Portable Can be used when away from mains electricity	(1)	2
	[Credit should be given for any reasonable correct physics point but not for generalised comments such as 'good for the planet' 'environmentally friendly']		

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• A standing wave is set up in the tube **Or** interference (of sound waves) takes place in the tube (1) • Where constructive interference occurs the amplitude is a maximum **Or** at antinodes the amplitude is a maximum (1) • Where destructive interference occurs the amplitude is a minimum **Or** at nodes the amplitude is zero/minimum (1) • Sand is displaced from points of max amplitude to points of min amplitude **Or** sand is displaced from antinodes to nodes (1)		4
(ii)	• Measure over at least 3 heaps (1) • Divide by the number of gaps between the heaps (1) • Repeat measurement and calculate average (1)	i.e at least 2 gaps	3
(iii)	• Use of $d = \frac{\lambda}{2}$ (1) • Use of $v = f\lambda$ (1) • v = 330 (m s^{-1}) and a comment on consistency with 340 m s^{-1} (1)	Example of calculation: $\lambda = 2d = 2 \times 5.1 \times 10^{-2}$ m = 0.102 m $v = 3.25 \times 10^{3}$ Hz × 0.102 m = 332 m s^{-1}	3

Q19.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Interference of soundwaves occurs in the tube (1) • (and a) stationary wave is formed **Or** nodes **and** antinodes are formed (1) • (where) constructive interference occurs the amplitude is maximum **Or** at antinodes the amplitude is maximum (1) • (where) destructive interference occurs the amplitude is zero/minimum **Or** at nodes the amplitude is zero/minimum (1) • Powder is displaced from points of max amplitude to min amplitude points **Or** Powder is displaced from antinode to nodes (1)		**5**

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
	C		**1**

Q21.

Question Number	Answer	Mark
	D	**1**

Q22.

Question Number	Answer	Mark
	A	**1**

Q23.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<u>Comparison of graphs</u> • maximum velocity of aluminium bat greater than wood (1) • (this is because) aluminium will store and then release more of the incident energy **Or** (this is because) aluminium is more elastic compared to wood (1) <u>Discussion of the position of the maximum velocity</u> **Max 2** • maximum velocity occurs at a node / $\frac{\lambda}{4}$ (1) • this produces no / minimal vibrations along the bat (1) • no / less energy transfer to bat to set up extra vibrations so maximum kinetic energy returned to ball (1) <u>Conclusion</u> • a statement that makes reference to baseball player being correct (1)	Conclusion mark is dependent on at least one graph mark and one postion mark	**(5)**

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
	• Waves are reflected at ends of strings (1) • The reflected waves meet and superpose/interfere (1) • Where they meet in phase constructive interference takes place producing points of maximum amplitude **Or** Where they meet in phase constructive interference takes place producing antinodes **Or** Where they meet in antiphase destructive interference takes place producing points of zero/minimum amplitude **Or** Where they meet in antiphase destructive interference takes place producing nodes (1)		3

Q25.

Question Number	Answer	Mark
	The only correct answer is C because decreasing the mass on the hanger decreases the tension in the string and, since $v = \sqrt{\frac{T}{\mu}}$, decreases the speed of waves on the string. $\lambda = v/f$ so the wavelength is shorter and a whole wavelength could fit in the original length A the wavelength at the original frequency is unchanged, so decreasing the length will not allow a whole wavelength B decreasing the frequency will increase the wavelength, since wave speed is unchanged, so this will not allow a whole wavelength D since $v = \sqrt{\frac{T}{\mu}}$, decreasing the mass per unit length will increase the wave speed, increasing the wavelength at the original frequency, so this will not allow a whole wavelength	1

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	
(i)	• Wear safety glasses (to protect eyes from breaking wire) **Or** wear suitable footwear (to protect feet from falling masses) **Or** place sand tray under masses (to catch them if they fall)		**1**

Question Number	Acceptable Answer		Additional Guidance	
(ii)	• $\lambda = 2L$ substituted into $v = f\lambda$ • v substituted into $v = \sqrt{\frac{T}{\mu}}$ • Correct re-arrangement into $y = mx + c$ format	**(1)** **(1)** **(1)**	$v = f\lambda$ and $\lambda = 2L$ so $v = 2fL$ $v = \sqrt{\frac{T}{\mu}}$, so $4f^2L^2 = \frac{T}{\mu}$ $L^2 = \left(\frac{T}{4\mu}\right).\frac{1}{f^2}$, so gradient is $\frac{T}{4\mu}$	**3**
(iii)	• Gradient calculated • Use of gradient = $\frac{T}{4\mu}$ • $\mu = 1.8$ (g m^{-1}) • SWG consistent with their calculated value of μ (24 swg)	**(1)** **(1)** **(1)** **(1)**	Example of calculation gradient = $\frac{(0.043 - 0)\text{m}^2}{(15.0 - 0.0) \times 10^{-6}\text{s}^2} = 2.87 \times 10^3\text{m}^2\text{s}^{-2}$ $\mu = \frac{2.1\text{ kg} \times 9.81\text{ m s}^{-2}}{4 \times 2.87 \times 10^3\text{m}^2\text{s}^{-2}} = 1.79 \times 10^{-3}\text{ kg m}^{-1}$ $\therefore \mu = 1.79\text{ g m}^{-1}$	**4**

Q2.

Question Number	Acceptable answers		Additional guidance	Mark
	• states wavelength = 1.2 cm	(1)	Example of calculation: $\lambda = 4.8 \times 0.25$ cm = 1.2 cm	
	• use of E = stress / strain	(1)	$A = \pi d^2 / 4$ $= \pi(3.6 \times 10^{-6}\ m)^2 / 4$ $= 1.012 \times 10^{-11}\ m^2$	
	• use of $A = \pi d^2/4$	(1)	stress = strain × E = 9.7×10^{-9} × 1.2×10^{9} N m^{-2}	
	• use of stress = F/A	(1)	= 11.64 N m^{-2} $T = F$	
	• use of $v = \sqrt{(T/\mu)}$	(1)	= stress × A = 11.64 N m^{-2} × 1.012×10^{-11} m^2 = 1.18×10^{-10} N	
	• use of $v = f\lambda$ with any two of the stated / measured / calculated values of v, f or λ to calculate the other	(1)	$v = \sqrt{(\ \div\ )} = \sqrt{8.92 \times 10^{-3}} =$ 0.094 m s^{-1} Using $v = f\lambda$, v = 7.9 Hz × 0.012 m = 0.0912 m s^{-1}	**7**
	• comparison of this calculated value of v, f or λ with the value obtained another way	(1)	Agree to within 3%, so suggests consistent	

Q3.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Calculate missing $f^2 = 9025$	(1)		
	• Plot missing point	(1)	Plot (35, 9025) or their calculated value of f^2	
	• Draw line of best fit	(1)		3

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Determines the gradient	(1)	e.g. gradient $= \frac{(10200-0)}{(40-0)} = 255$	5
	• Equates $v = f\lambda$ and $v = \sqrt{\frac{T}{\mu}}$	(1)	accept $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$	
	• Uses $\lambda = 0.8$ (m)	(1)		
	• Mass per unit length μ = (6.0 to 6.2) x 10^{-3} (kg m^{-1})	(1)	$\mu = \frac{1}{255 Hz^2 N^{-1} \times 0.8^2 m^2} = 6.1 \times 10^{-3}$ (kg m^{-1})	
	• Conclusion consistent with their value	(1)		

Q4.

Question Number	Answer	Mark
	C increasing the length of the string	**1**
	Incorrect Answers: **A** results in a higher value for f **B** results in a higher value for f **D** results in a higher value for f	

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of stress = F/A	(1)	Example of calculation stress = 93.4 N / 6.6×10^{-7} m^2 = 1.42×10^8 N m^{-2} strain = 1.42×10^8 N m^{-2} / 1.8×10^9 N m^{-2} = 0.0786 extension = 0.0786 × 0.68 m = 0.053 m	4
	• Use of Young modulus = stress / strain	(1)		
	• Use of strain = $\Delta x/x$	(1)		
	• Extension = 0.053 m	(1)		
(ii)	• Increase tension so increase wavespeed since $v = \sqrt{\frac{T}{\mu}}$ **Or** decrease μ so increase wavespeed since $v = \sqrt{\frac{T}{\mu}}$	(1)		2
	• Since $v = f\lambda$ and wavelength unchanged, this increases frequency	(1)		

Q6.

Question Number	Answer	Mark
	D – increases non-linearly	**1**
	Incorrect Answers: A – incorrect as $f \propto \sqrt{T}$ B – incorrect as $f \propto \sqrt{T}$ C – incorrect as $f \propto \sqrt{T}$	

Q7.

Question Number	Answer	Mark
	C - $\mu = \frac{1}{\text{gradient}}$	**1**
	Incorrect Answers: A – incorrect use of $v = \sqrt{\frac{T}{\mu}}$ B – incorrect use of $v = \sqrt{\frac{T}{\mu}}$ D - incorrect use of $v = \sqrt{\frac{T}{\mu}}$	

Q8.

Question Number	Answer	Mark
	D Comparing to y=mx+c format with v as y and $\sqrt{T}$ as x	**1**
	Incorrect Answers: A – this assumes T is proportional to $\sqrt{v}$ B – this assumes v is proportional to T C – this assumes $\frac{1}{T}$ is proportional to v	

Q9.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Wavelength = 44 cm	(1)		1
(ii)	• Use of $v = \sqrt{\frac{T}{\mu}}$ • Use of $v = f\lambda$ (ecf from (i)) • f = 320 Hz	(1) (1) (1)	Example of calculation $v = \sqrt{\frac{88.6\ \text{N}}{4.47 \times 10{-}3\ \text{kg m}{-}1}}$ $= 141\ \text{m s}^{-1}$ $f = 141\ \text{m s}^{-1} / 0.44\ \text{m}$ $= 320\ \text{Hz}$	3

Q10.

Question Number	Answer	Mark
	A 0.4 + 0.05 Incorrect Answers: B – compound uncertainties by addition C – compound uncertainties by addition D – compound uncertainties by addition	1

Mark Scheme

Q1.

Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is **C** because the corrected count rate at 30 cm is 40 counts per minute, the corrected rate at twice the distance is a quarter of this value, which is 10 counts per minute, and adding the background gives the value of 34 A is not the correct answer because it is 16 C is not the correct answer because it is 32 D is not the correct answer because it is 44	**1**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $W = VIt$ (1) • use of $\Delta E = mc\Delta\theta$ (1) • use of efficiency = useful power output / total power input (1) • efficiency = 0.90 Or 90% (1)	Example of calculation: W = 247 V × 11.8 A × 172 s = 501 000 J ΔE = 1.20 kg × 4180 J kg^{-1} K^{-1} × (101 - 11) K = 451 000 J Efficiency = 451 000 / 501 000 = 0.90	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• calculates area of sphere of radius 30 cm = 1.13 m^2 (1) • use of $I = P/A$ (1) • use of $W = Pt$ (1) • W = 2.0 J (1)	Example of calculation: Area = 4π × (0.3 m)^2 = 1.13 m^2 P = 10.5 × 10^{-3} W m^{-2} × 1.13 m^2 = 1.19 × 10^{-2} W W = 1.19 × 10^{-2} W × 172 s = 2.0 J	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	An explanation that makes reference to the following: • the quiet boil electric kettle is more efficient, but only by 3% which isn't 'much' (1) • the energy transferred by sound is very small, so it is not the reason for the difference (1)	Allow 1 mark if the student gives a comment that the uncertainties are too high to draw a valid conclusion without reference to the data in the question, the candidate's calculations may be awarded one mark	**(2)**

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • Radiation is absorbed/scattered passing through the atmosphere. (1) • Radiation is reflected from the top of the atmosphere (1) • Only half of the Earth's surface has radiation from the Sun incident on it at any one instant. (1) • The intensity of radiation (normal to the surface) is greater at the equator than at the poles. (1)		**4**
(ii)	• Use of $A=4\pi r^2$ (1) • Use of efficiency= $\frac{\text{useful power output}}{\text{total power input}}$ (1) • Use of $I=\frac{P}{A}$ (1) • % of surface needed is 0.0005%, so claim is not valid (1) [Accept reverse calculation to show power generated by cells over 0.5% of the Earth would generate 1.06×10^5 GW]	Example of calculation: $A=\frac{P}{I}$ $=\frac{100\times10^9\ \text{W}}{0.25\times164\ \text{W m}^{-2}}=2.44\times10^9\text{m}^2$ $A=4\pi\times(6.4\times10^6\ \text{m})^2$ $=5.15\times10^{14}\text{m}^2$ % needed = $\frac{2.44\times10^9\text{m}^2}{5.15\times10^{14}\ \text{m}^2}\times100\%=0.00047\ \%$	**4**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ **(1)** • $c = 67^\circ$ **(1)** • Determines the angle of incidence is 70° **(1)** • so i > c so the ray does totally internally reflect **(1)**	Example of calculation: $1.56 \times \sin c = 1.44 \times \sin 90^\circ$ $c = 67.4^\circ$	**4**

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	Either • The wavelength of the electron is less than the wavelength of light (1) • (So) less diffraction (with the electron beam) (1) **Or** (1) • The wavelength of the light is greater than the wavelength of the electrons (1) • (So) more diffraction (with light beam)		**2**

Q2.

Question Number	Answer	Mark
	A	1

Q3.

Question Number	Answer	Mark
(a)	Human body contains water molecules **Or** body has same structure as food (1) So cells/tissues would gain internal energy (1) (Accept cells/tissues would be heated)	2
(b) (i)	Waves spread out (1) After passing through a gap **Or** after passing around an obstacle (1)	2
(b)(ii)	Use of $c = f\lambda$ with $c = 3.0 \times 10^8$ m s^{-1} (1) $\lambda = 0.12$ m (1) Example of calculation $\lambda = 3.0 \times 10^8$ m s^{-1} ÷ 2.5×10^9 Hz $\lambda = 0.12$ m	2
(b)(iii)	Diameter = 2mm (1)	1
*(b)(iv)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Diffraction greatest when wavelength is about the same as gap size (1) Diameter of holes much greater than wavelength of light **and** diameter of holes less than microwave wavelength (1) so no/little diffraction of light takes place **Or** so microwave radiation still diffracted through large angle but intensity is very small. (1) MP3 must follow on from relevant part of MP2	3

Q4.

Question Number	Acceptable Answers	Additional Guidance	Mark
	A		1

Q5.

Question Number	Answers	Mark
	The only correct answer is B ***A** is incorrect because amplitude does not affect the diffraction effect* ***C** is incorrect because frequency affects the wavelength and hence the diffraction effect* ***D** is incorrect because the speed of sound affects the wavelength and hence the diffraction effect*	1

Q6.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An explanation that makes reference to: • waves/light passing through a narrow gap spread/s out **(1)** • light reaches the wall from each part of the slit with differing phase relationships **(1)** **OR** light reaches the wall from each part of the slit with differing path lengths **(1)** • when the waves meet superposition takes place and if the waves are in antiphase it results in destructive interference so a dark spot is seen **(1)** **OR** when the waves meet superposition takes place and if the waves are in phase it results in constructive interference so a bright(er) region is seen **(1)**	Accept relevant reference to Huygen's construction for first mark.	**3**
(b)	An explanation that makes reference to: • green light has a shorter wavelength than red light **(1)** **OR** red light has a longer wavelength that green light **(1)** • so green light diffracts less than red light **or** red light diffracts more than green light **(1)** • so the dark points would be closer to the centre or more dark points would be seen in the same space on the wall or central fringe narrower **(1)**	Accept a diagram clearly to the same scale and showing a narrowed pattern. MP2 and MP3 may be awarded if reference is made to frequency difference rather than wavelength.	**3**
(c)	• use of trigonometrical functions to calculate θ **(1)** • calculate diffraction grating spacing **(1)** • wavelength = 5.1×10^{-7} m **(1)**	Example of calculation: $\theta = \tan^{-1}(0.23\text{ m}/1.5\text{ m}) = 8.7°$ $d = 10^{-3}/300 = 3.3 \times 10^{-6}$ m $\lambda = 3.3 \times 10^{-6}$ m $\times \sin 8.7°$ $= 5.1 \times 10^{-7}$ m	**3**

Q7.

<table>
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Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5 - 4</td><td>3</td></tr>
<tr><td>3 - 2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td></td></tr>
</table>

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<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
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Question Number	Acceptable Answer	Additional Guidance	Mark
* (continued)	**Indicative content** • Analyses and interprets the text to conclude that diffraction occurs when light is reflected from the CD surface • Each ring on the CD acts as a diffraction centre scattering light in all directions • Interference occurs (superposition of light from the multiple light sources) • In directions in which there is a phase difference equal to an even multiple of π rad constructive interference (reinforcement) occurs **OR** in directions in which there is a path difference equal to a whole number of wavelengths constructive interference (reinforcement) occurs • White light is a range (mixture) of wavelengths • Hence each wavelength of light reinforces in a different direction which explains why a spectrum is seen		**6**

Q8.

Question Number	Answer		Mark
(a)	Photon – quantum/packet of something relevant e.g. light, radiation, any other named e-m radiation, energy (quantum/packet) of <u>electromagnetic</u> energy/radiation/waves (dependent mark)	**(1)** **(1)**	**2**
(b)	Use of $(20.66 - 18.70) \times 1.6 \times 10^{-19}$ Use of $E = hf$ (with energy in eV or J) $f = 4.7 \times 10^{14}$ Hz <u>Example of calculation</u> $f = (20.66 - 18.70) \times 1.6 \times 10^{-19} \ / \ 6.63 \times 10^{-34}$ $f = 4.73 \times 10^{14}$ Hz	**(1)** **(1)** **(1)**	**3**
(c)	From kinetic energy of atoms	**(1)**	**1**
(d)	Diffraction Light spreads (sideways) as it passes through the slit Narrower slit causes more diffraction/spreading **Or** diffraction increasing as gap width gets closer to wavelength	**(1)** **(1)** **(1)**	**3**
	Total for question		**9**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	An explanation that makes reference to the following: • The light is diffracted (1) • (because) each point on wavefront acts as a source of secondary waves **Or** wavelets emitted (from points on the wavefront) (1)	Marks may be shown on a clearly labelled diagram	2

Question Number	Acceptable answers	Additional guidance	Mark
(b)	An explanation that makes reference to the following: • Path lengths (to centre of shadow from edge of ball) are equal (1) **Or** path difference (at spot) is zero • Will arrive in phase **Or** phase difference is zero (1) • (Bright spot is position of) constructive interference/superposition (1)		3

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• The wave spreads out (after passing through a gap) (1) • Each point on the wave acts as a source of (secondary) wavelets (1) • That interfere/superpose (1)		3

Q11.

Question Number	Answer	Mark
*(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) The waves superpose **Or** diffraction at the double slits **(1)** Where they are in phase **Or** when path difference is a whole number of wavelengths constructive interference takes place **(1)** Where they are in antiphase / when path difference is an odd number of half wavelengths destructive interference takes place **(1)** Bright bands are when waves are in phase / when path difference is nλ / constructive interference **Or** reverse for dark bands **(1)**	**4**
(b)	coherent = constant phase relationship/difference (between light arriving from the two sources) **Or** if they are not coherent the phase relationship/difference will vary. **(1)** The idea that at a given point there would sometimes be constructive interference and sometimes destructive interference etc **(1)**	**2**
(c)	Interference (accept diffraction) only occurs with waves. **(1)**	**1**
	Total for question	**7**

Q12.

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<tr><td></td><td>Indicative content

• This is a diffraction/interference pattern

• Electrons behave as waves

• As speed/momentum increases the circles get smaller

• n$\lambda = d\sin\theta$ used to justify that as θ decreases λ decreases

• Refers de Broglie equation ($\lambda = h/p$) to confirm that as speed/momentum increases, wavelength decreases.

• Crystal has a regular/layered structure</td><td>PP2 Do not credit 'electrons behave as waves or particles' on its own
PP3 accept circles get condensed for circles get smaller

PP4 do not credit use of equation to justify λ same size as gaps in crystal or to measure the gaps in the graphite

PP6 small gaps at uniform distances/lengths Or accept that graphite is made up of more than a single crystal</td><td>6</td></tr>
</table>

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Q13.

Question Number	Answer	Additional guidance	Mark
	D		**(1)**

Q14.

Question Number	Answers	Additional Guidance	Mark
	A	diffraction	**(1)**

Q15.

Question Number	Acceptable Answers		Additional guidance	Mark
(i)	• Use of node to node distance = $\frac{\lambda}{2}$ • Use of $v=f\lambda$ • v = 340 m s^{-1}	(1) (1) (1)	Example of Calculation λ = 2 x 0.86 m = 1.72 m v = 200 s^{-1} x 1.72 m = 344 m s^{-1}	**3**
(ii)	• Wavelength is 1.7 m which is the same order of magnitude as 2 m • Diffraction will take place so sound will be heard at Y	(1) (1)	Example of Calculation λ = 2 x 0.86 (m) = 1.7 m	**2**

Mark Scheme

Q1.

Question Number	Answer	Mark
(a)	Change in direction of wave (accept ray or any named wave) (do not accept bend) (1) (Due to) change in (optical) density / speed / medium (1)	2

Question Number	Answer	Mark
(b)	There is no change in direction for the light (passing between the water and the gel) **Or** There is no refraction (as the light passes between the water and the gel) (accept … within the beaker) (1) The light must have the same/similar wave speed in the water and gel (1) (accept same/similar density for water and gel)	2

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	• Glass reflects (these wavelengths of) IR radiation (1) • Glass does not transmit (these wavelengths of) IR radiation (1)	Accept IR does not pass through glass	2

Q3.

Question Number	Answer		Mark
(a)	Particles/atoms/ions/molecules (in metal) oscillate/vibrate	**(1)**	
	Along direction of propagation **Or** parallel to direction of wave travel **Or** in direction of energy transfer (along direction of motion/movement is insufficient)	**(1)**	
	Making compressions and rarefactions **Or** as a longitudinal wave	**(1)**	**3**
(b)	Use of $s = vt$	**(1)**	
	Correct application of factor of 2	**(1)**	
	Answer, $s = 0.015$ m **Or** total journey time for thickness 4 cm = 1.4×10^{-5} s	**(1)**	
	Comparison – Steel is corroded because thickness less than 4 cm (allow even if no division by 2) **Or** Steel is corroded because detected time less than for 4 cm (allow even if no division by 2)	**(1)**	**4**
	(For third mark, accept $s = 0.030$ m where final comparison is with total uncorroded journey distance, 8 cm **Or** time = 6.8×10^{-6} s where final comparison is with half of corroded journey time 2.6×10^{-6} s)		
	<u>Example of calculation</u> $s = 5900 \text{ m s}^{-1} \times 5.1 \times 10^{-6}$ s = 0.030 m Thickness = 0.030 / 2 = 0.015 m		
(c)	Need to measure time at which the echo arrives back **Or** need to measure time taken for echo to return	**(1)**	
	If continuous couldn't tell when this was **Or** so pulse must return before next is emitted	**(1)**	
	Shorter pulses means smaller thickness can be measured **Or** longer pulses means only larger thickness can be measured	**(1)**	**3**
	Total for question		**10**

Q4.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Light is refracted as it passes into medium 2 **(1)** • Angle of refraction may be calculated using $n_1\sin\theta_1 = n_2\sin\theta_2$ **(1)** • Angle of refraction = 89.81° **(1)** • Angle of <u>incidence</u> at layer 2-3 is greater than the critical angle **(1)** • So <u>total internal reflection</u> occurs (at layer 2-3 interface) **(1)** • So light/ rays appear to come from surface of road (so that observer sees mirage) **(1)**	MP2 see use of the equation MP5 accept totally internally reflected and TIR MP6 is not just for saying there is a mirage. <u>Example of Calculation</u> $\sin^{-1}\left(\frac{1.00032 \times \sin 89.59°}{1.00030}\right)$ $= 89.81°$	**6**

Q5.

Question Number	Answer	Mark
(a)	To be able to distinguish which reflection comes from which emission **Or** so one pulse returns before the next one is emitted **(1)**	**1**
(b)	Use of $v = s/t$ **(1)** Correct use of factor of 2 (double distance or double time) **(1)** Pulse duration = 2.4×10^{-3} s (0.0024 s, 2.4 ms) **(1)** <u>Example of calculation</u> Time = 2×0.4 m $\div$ 330 m s^{-1} Pulse duration = 2.4×10^{-3} s	**3**
(c)	(Ultrasound) <u>reflected</u> away from the sensor **Or** (Ultrasound) <u>reflected</u> towards the floor **(1)**	**1**
	Total for Question	**5**

Q6.

Question Number	Answer		Mark
(a)	change in direction / wavelength (of wave/ray/light) (when entering a medium where) the wave has a different velocity **OR** (when entering a medium where) the density is different the light travels at a lower speed in the air than in a vacuum	(1) (1) (1)	3
(b)	identify angle of incidence = 64° use of sin i / sin r = refractive index r = 63.9° to at least 3 sf calculation of difference = 0.12° <u>Example of calculation</u> sin r = sin i ÷ μ = sin 64° ÷ 1.001 r = 63.88° difference = 0.12°	(1) (1) (1) (1)	4
	Total for question		7

Q7.

Question Number	Answer		Mark
(a)	(When light strikes a boundary with) angle of incidence greater than the critical angle **Or** When light within a denser medium strikes a boundary with a less dense medium All of the light is reflected **Or** none of the light is transmitted **Or** none of the light is refracted	(1) (1)	2

Question Number	Answer		Mark
(b)(i)	Use of μ = sin i / sin r x = 41(°) <u>Example of calculation</u> sin x = sin 60° / 1.33 x = 40.6°	(1) (1)	2
(b) (ii)	Use of μ = sin i / sin r with i = 90° (accept stating sin c = 1 / μ) c = 49(°) <u>Example of calculation</u> μ = sin 90° /sin c sin c = 1 / μ = 1 / 1.33 c = 49°	(1) (1)	2
(b) (iii)	Angle in gel < critical angle **Or** angle y < critical angle **Or** (If angle x = angle y, then this corresponds to an) angle in air of 60° Not total internal reflection so some light reaches screen **Or** Light will be refracted/transmitted so some light reaches screen	(1) (1)	2

Mark Scheme

Q1.

Question Number	Acceptable Answers		Additional guidance	Mark
(a)	• Sound travels as a longitudinal wave **Or** in a series of compressions **and** rarefactions • With oscillations/vibrations of (air) particles/molecules parallel to the direction of energy transfer	(1) (1)	Accept: Direction of energy transfer **Or** propagation of the wave **Or** direction of wave travel/motion	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(i)	• the idea that there is a wide variation in the first two readings	(1)		1

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(ii)	• uses $\frac{\text{half the range of values}}{\text{mean value}}$ • percentage uncertainty = 8.5%	(1) (1)	Example of Calculation $\frac{0.5 \times (0.51\ s - 0.43\ s)}{0.47\ s} \times 100\% = 8.5\%$ Accept calculations based on $\frac{\text{range of values}}{\text{mean value}}$ (17%)	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(iii)	• attempt to calculate Δv • $\Delta v = 7.4\ m\ s^{-1}$ or $8.0\ m\ s^{-1}$	(1) (1)	Example of Calculation $\frac{160\ m}{0.46\ s} - \frac{160\ m}{0.47\ s} = 7.4\ m\ s^{-1}$ Use of 80 m (Δv =3.7) scores MP1 only	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(iv)	**Max 2:** • insufficient number of results • identifies one other variable to take into account • difference (in t or v) could be due to human reaction times • uncertainty in results may account for the difference	(1) (1) (1) (1)	Do not accept take readings over more days MP2 examples:wind speed/direction, humidity, air pressure MP3 do not credit human error	2

Q2.

Question Number	Acceptable Answers	Additional Guidance	Mark
	D		1

Q3.

Question Number	Answer		Mark
(a)	Particles/atoms/ions/molecules (in metal) oscillate/vibrate	**(1)**	
	Along direction of propagation **Or** parallel to direction of wave travel **Or** in direction of energy transfer (along direction of motion/movement is insufficient)	**(1)**	
	Making compressions and rarefactions **Or** as a longitudinal wave	**(1)**	**3**
(b)	Use of $s = vt$	**(1)**	
	Correct application of factor of 2	**(1)**	
	Answer, $s = 0.015$ m **Or** total journey time for thickness 4 cm = 1.4×10^{-5} s	**(1)**	
	Comparison – Steel is corroded because thickness less than 4 cm (allow even if no division by 2) **Or** Steel is corroded because detected time less than for 4 cm (allow even if no division by 2)	**(1)**	**4**
	(For third mark, accept $s = 0.030$ m where final comparison is with total uncorroded journey distance, 8 cm **Or** time = 6.8×10^{-6} s where final comparison is with half of corroded journey time 2.6×10^{-6} s)		
	Example of calculation $s = 5900 \text{ m s}^{-1} \times 5.1 \times 10^{-6}$ s = 0.030 m Thickness = 0.030 / 2 = 0.015 m		
(c)	Need to measure time at which the echo arrives back **Or** need to measure time taken for echo to return	**(1)**	
	If continuous couldn't tell when this was **Or** so pulse must return before next is emitted	**(1)**	
	Shorter pulses means smaller thickness can be measured **Or** longer pulses means only larger thickness can be measured	**(1)**	**3**
	Total for question		**10**

Q4.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Use of $v = \frac{s}{t}$ with $v = 3.00 \times 10^8$ (m s^{-1})	(1)	Example of Calculation $s = \frac{3.00 \times 10^8 \text{ m s}^{-1} \times 3.4 \times 10^{-4} \text{ s}}{2}$	
	• Correct use of factor of 2	(1)	s = 51000 m	
	• distance = 51000 m	(1)		3

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Q5.

Question Number	Answer	Mark
(a)	To be able to distinguish which reflection comes from which emission **Or** so one pulse returns before the next one is emitted **(1)**	1
(b)	Use of $v = s/t$ **(1)** Correct use of factor of 2 (double distance or double time) **(1)** Pulse duration = 2.4×10^{-3} s (0.0024 s, 2.4 ms) **(1)** Example of calculation Time = 2×0.4 m $\div$ 330 m s^{-1} Pulse duration = 2.4×10^{-3} s	3
(c)	(Ultrasound) reflected away from the sensor **Or** (Ultrasound) reflected towards the floor **(1)**	1
	Total for Question	5

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• they detect the reflection of their clicks (1) • the closer an obstacle is the shorter the time interval between the clicks returning (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• use of $s = vt/2$ (to find pulse length / 2 as minimum distance to object) (1) • $s = 0.33$ m (1) • use of $v = f\lambda$ (1) • $\lambda = 0.17$ m (1) • half pulse length needs to be less than distance and half wavelength needs to be less than distance; both are, so clicks are suitable (1)	<u>Example calculation</u> $s = vt/2$ $= 330 \text{ m s}^{-1} \times 2 \times 10^{-3} \text{ s} / 2$ $s = 0.33$ m $\lambda = v/f$ $= 330 \text{ m s}^{-1} / 2 \times 10^{3} \text{ Hz}$ $= 0.17$ m	**(5)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• the bird needs to distinguish between received clicks, so one must be received before the next is sent (1) • at larger distances more time must be allowed for clicks to return <u>OR</u> as the bird gets closer to an obstacle more frequent updates on the position are required (1)		**(2)**

Q7.

Question Number	Answer	Additional Guidance	Mark
	• Use of $v = \frac{s}{t}$ with a factor of 2 (1) **Either** • $t = 125\ \mu s$ (1) • Comparison of their calculated value with 160 µs to reach a conclusion consistent with their answer (1) **Or** • $s = 0.256\ m$ (1) • Comparison of their calculated value with 0.2 m to reach a conclusion consistent with their answer (1)	<u>Example of calculation</u> $s = \frac{3200\ m\ s^{-1} \times 1.25 \times 10^{-4}\ s}{2}$ $= 0.2\ m$ $t = \frac{2 \times 0.2\ m}{3200\ m\ s^{-1}} = 250\ \mu s$ 125 µs < 160 µs so detected	3

Q8.

Q	Acceptable Answers	Additional guidance	M
	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. **IC points / IC mark / Max linkage mark / Max final mark** **6 / 4 / 2 / 6** **5 / 3 / 2 / 5** **4 / 3 / 1 / 4** **3 / 2 / 1 / 3** **2 / 2 / 0 / 2** **1 / 1 / 0 / 1** **0 / 0 / 0 / 0** **Indicative Content** **IC1** Pulses of light are emitted from laser/Earth **or** Pulses of light sent to the Moon/mirror **IC2** Light reflects from the mirrors **IC3** Measure the time taken for the reflected light to return **IC4** Calculate distance = speed x time **IC5** Use speed of light c **IC6** Measured time must be divided by 2 **Or** calculated distance must be divided by 2	The following table shows how the marks should be awarded for structure and lines of reasoning Number of marks awarded for structure of answer and sustained line of reasoning Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout: 2 Answer is partially structured with some linkages and lines of reasoning: 1 Answer has no linkages between points and is unstructured: 0	6

Q9.

Question Number	Answer		Mark
(a)	Use of distance = speed x time Time = 1.7 x 10^{-8} s Example of calculation $t = s \div v$ = 5.0 m ÷ 3.0 × 10^{8} m s^{-1} Time = 1.67 x 10^{-8} s	(1) (1)	2
(b)	Pulses, so the reflected signal is received before next one is sent **Or** otherwise there wouldn't be a way of telling which bit of reflected IR originated with which bit of emitted IR **Or** so that reflected pulses can be distinguished from each other	(1)	1
(c)	Accept any sensible reason, Examples: could interfere with what is being looked at light from the background could interfere with the signal	(1)	1
	Total for question		4

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $c=f\lambda$ and $E=hf$ **(1)** • Converts eV to J **(1)** • Use of $E = W + KE_{max}$ **(1)** • KE_{max} = 1.3 × 10^{-19} J **(1)**	Example of calculation: $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\text{Js}\times3\times10^{8}\text{m s}^{-1}}{2.54\times10^{-7}\text{m}} = 7.831\times10^{-19}\text{J}$ Work function = 6.51 × 10^{-19} J $E = W + KE_{max}$ $KE_{max} = 7.83\times10^{-19}\text{J} - 6.51\times10\text{ -}19\text{J} = 1.32\times10^{-19}\text{J}$	4

Q11.

Question Number	Answer	Mark
	C $t = \frac{90 \times 2}{1500}$	1
	Incorrect Answers: A -no factor of 2 B - no factor of 2 and incorrect equation D - incorrect equation	

Q12.

Question Number	Answer	Mark
	C the reflected pulse can be detected before the next pulse is transmitted	**1**
	Incorrect Answers: A – incorrect B – This is limited by the wavelength D – Diffraction is affected by wavelength	

Q13.

Question Number	Acceptable Answers	Additional Guidance	Mark
	Analyses data by: • use of $v = f\lambda$ **(1)** • $\lambda = 6 \times 10^{-4}$ m **(1)** • stone about 4 mm from photo **(1)** **AND** • concludes this would give sufficient resolution at this frequency because the wavelength is less than half the size of the kidney stone **(1)**	Example of calculation: 1500 m s^{-1} = 2.5 $\times 10^6$ Hz $\times \lambda$ $\lambda = 6 \times 10^{-4}$ m	**4**

Q14.

Question Number	Answer	Mark
	C $\frac{3.0\times10^{8}\times t}{2}$	1
	Incorrect Answers: A – incorrect factor of 2 B – incorrect factor of 2 and speed D – incorrect speed	

Q15.

Question Number	Answer	Mark
	The only correct answer is A because detail is improved by both decreasing pulse length and decreasing wavelength B increasing wavelength decrease detail C increasing pulse length decrease detail D increasing pulse length and increasing wavelength both decrease detail	1