# Mark scheme – Wave Motion

| Question | | | Answer/Indicative content | Marks | Guidance |
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| 1 | | | **C** | **1** | **Examiner's Comments**<br>All questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A require careful inspection. Candidates can underline or circle key information to make the questions accessible. Whilst highlighter pens may be used to identify useful information in the printed question, they must not be used to record any part of the answer as they are not visible when scanned. No detailed calculations are expected on the pages, so any shortcuts, or intuitiveness, can be employed to get to the correct answers.<br>Questions **1, 4, 5, 7, 10** and **12** proved to be particularly straightforward, allowing most of the candidates to demonstrate their knowledge and understanding of physics. Question **10** tested the learning outcome 4.5.1(e)(i) on LEDs; a good number of candidates successfully rearranged the expression $eV = hc/\lambda$ to get the correct answer **D.**<br>At the other end of the scale, Questions **2, 8, 9** and **14,** proved to be more challenging.<br><br>• Question **2** was about the refraction of light through a triangular glass prism. The most popular distractors were **D** and **B,** where the incident and emergent rays were parallel. Perhaps the candidates were thinking about a rectangular block, where such rays are parallel. Only a quarter of the candidates got the correct answer **C.**<br>• Question **8** was about two resistors in a parallel combination and percentage uncertainty. The correct answer was **A.** The popular distractor was **B** where the candidates simply added the percentage uncertainties for each resistor. The best way of tackling this tough question was to use the equation $1/R = 1/R_1 + 1/R_2$ to calculate either the maximum or the minimum value of the total resistance $R$ and then the percentage uncertainty. This question was accessible to only a quarter of the candidates.<br>• Question **9** was about a potential-divider circuit with an LDR. The resistance of the LDR increases when the intensity of the light is reduced. The smaller current in the circuit would lead to a smaller p.d. across the fixed resistor. The answer had to be **A.** On the back of some erroneous analysis, the most frequent answer was **B.**<br>• Question **14** was about the de Broglie wavelength of an electron when the accelerating p.d. is doubled. Less than a third of the candidates got the correct answer **B.** All the other distractors were equally popular. The logical way to tackle this would have been as follows:<br>  ○ $KE = e \times V$; doubling the p.d. $V$ will double the kinetic energy of the electron.<br>  ○ $KE = \frac{1}{2}mv^2$; the speed $v$ of the electron will increase by a factor of $\sqrt{2}$. |

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| | | | | | ○ $\lambda p = h$; the wavelength $\lambda$ will decrease by a factor of $\sqrt{2}$. |
| | | | **Total** | **1** | |
| 2 | | | **D** | 1 | |
| | | | **Total** | **1** | |
| 3 | | | B | 1 | |
| | | | **Total** | **1** | |
| 4 | | | C | 1 | |
| | | | **Total** | **1** | |
| 5 | | | **A** | 1 | |
| | | | **Total** | **1** | |
| 6 | | | **A** | **1** | |
| | | | **Total** | **1** | |
| 7 | | | C | 1 | **Examiner's Comments**<br><br>All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions.<br><br>The candidates to demonstrate their knowledge and understanding of physics. |
| | | | **Total** | **1** | |
| 8 | | | D | 1 | |
| | | | **Total** | **1** | |
| 9 | | | **B** | **1** | |
| | | | **Total** | **1** | |
| 10 | | | **C** | **1** | |
| | | | **Total** | **1** | |
| 11 | | | **C** | 1 | |
| | | | **Total** | **1** | |
| 12 | | | A | 1 | |

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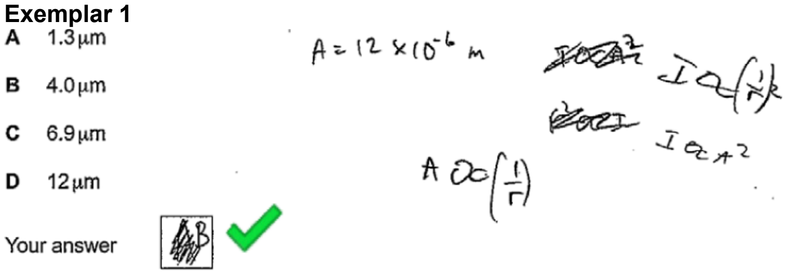
| | | | **Total** | **1** | |
| 13 | | | B | 1 | |
| | | | **Total** | **1** | |
| 14 | | | B | 1 | |
| | | | **Total** | **1** | |
| 15 | | | **B** | 1 | **Examiner's Comments**<br><br>The emission of sound *'uniformly in all direction'* was the clue that the intensity of the wave followed an inverse square law relationship with distance from the source. The intensity is also directly proportional to amplitude$^2$. This meant that amplitude of the wave is inversely proportional to the distance from the source. The correct answer (key) for this question is **B**. The most popular distractor was **C**, where 12 μm was divided by √3.<br><br>**Exemplar 1**<br><br>This exemplar illustrates the sensible strategy from a top-end candidate.<br><br>The key ideas are jotted down and analysis completed: $I \propto 1/r^2$ and $I \propto A^2$, therefore $A \propto 1/r$.<br><br>The distance $r$ increases by a factor of 3, therefore the amplitude will decrease by a factor of 3. This makes the answer 4.0 μm. The final sum being done either in the head or calculator – this is of little significance. What is important here is that all the important ideas have been extracted competently from the question. A commendable technique. |
| | | | **Total** | **1** | |
| 16 | | | **A** | 1 | |
| | | | **Total** | **1** | |
| 17 | | | A | 1 | |
| | | | **Total** | **1** | |
| 18 | | | **B** | 1 | |

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| | | | **Total** | **1** | |
| 19 | | | C | 1 | **Examiner's Comments**<br><br>The correct response is **C**. Although not a particularly challenging question, it was encouraging to see around three quarters of entrants getting the correct solution. The most common incorrect response was **A**, suggesting that the idea of time period is not necessarily well understood. |
| | | | **Total** | **1** | |
| 20 | | | B | 1 | **Examiner's Comments**<br><br>The correct response is **B**. Around two thirds of candidates were able to correctly calculate the frequency; this question relies on the candidate appreciating that there is more than one complete cycle in the tube and then evaluating the correct wavelength. It is then a straightforward calculation. As expected, most of the incorrect responses were **A**, where the wave equation had simply been used with the given numbers. Several candidates drew on the diagram to help in their calculation of the wavelength, although some thought that the wavelength was two thirds of the tube length, rather than four fifths. |
| | | | **Total** | **1** | |
| 21 | | | C | 1 | |
| | | | **Total** | **1** | |
| 22 | | | A | 1 | **Examiner's Comments**<br><br>The correct response is **A**. This question was correctly answered by the vast majority of candidates, who were able to select the correct terms applicable. |
| | | | **Total** | **1** | |
| 23 | | | **A** | 1 | |
| | | | **Total** | **1** | |
| 24 | | | **A** | 1 | |
| | | | **Total** | **1** | |
| 25 | | | time | B1 | **Allow** *t* but **not** *T*<br>**Ignore** any correct unit given with the correct label<br>**Not** a wrong unit with the correct label, e.g *t* / m (CON)<br>**Not** just a unit of time, e.g. second<br><br>**Examiner's Comments**<br><br>Almost all candidates did well here by correctly labelling the horizontal axis. Most answers also included the unit, e.g. time / s. A very small |

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| | | | | | number of candidates had *distance, time period, frequency* and *velocity* for the label. |
| | | | **Total** | **1** | |
| 26 | | | **A** | 1 | |
| | | | **Total** | **1** | |
| 27 | | | C | 1 | |
| | | | **Total** | **1** | |
| 28 | a | | constant phase (difference of 90°) | B1 | **Ignore** incorrect value<br>**Ignore** same wavelength / frequency / period |
| | b | | (period =) 4.0 (ms)<br>($f$ = $0.004^{-1}$)<br>$f$ = 250 (Hz) | C1<br><br>A1 | **Allow** 1 mark for 0.25; k omitted |
| | c | | (intensity =) $\left(\frac{24}{10}\right)^2(I_0)$<br>intensity = 5.8 ($I_0$) | C1<br>A1 | **Not** $\frac{144}{25}I_0$<br>**Allow** 1 mark for 4.84; misread graph and used $(\frac{22}{10})^2$ |
| | d | | resultant displacement = 10 (μm) | B1 | **Allow** ± 1.5; **Ignore** sign |
| | | | **Total** | **6** | |
| 29 | | | $3.0 \times 10^8 = f \times 2.5 \times 10^{-11}$<br>$f = 1.2 \times 10^{19}$ (Hz) | C1<br>A1 | |
| | | | **Total** | **2** | |
| 30 | a | i | 40 (mV) | B1 | **Examiner's Comments**<br>This was well answered. A few candidates gave an answer of 80 mV. |
| | | ii | ($T$ =) 3 × 0.5 = 1.5 (ms) | C1 | |
| | | ii | $f$ = 670 (Hz) | A1 | **Note**: Answer to 3 SF is 667 (Hz)<br>**Note**: 0.67 or 0.667 scores 1 mark<br>**Examiner's Comments**<br>This was also well answered although some candidates did not allow for the milliseconds. |
| | | iii | (330 = 670 x λ) | | **Possible** ECF from **(ii)**<br>**Note**: λ = 0.495 (m) if 667 Hz is used, therefore allow |
| | | iii | λ = 0.49 (m) | B1 | 0.50 or 0.5 (m) here<br>**Examiner's Comments** |

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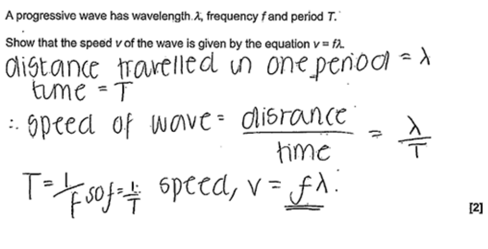
| | | | | | Most candidates correctly rearranged the formula and used their answer to (ii). Some candidates truncated their answer to one significant figure which was not penalised this year. |
| | b | | Amplitude / height (of trace / signal) is smaller | B1 | |
| | | | $I \propto A^2$ <u>and</u> amplitude (of sound or signal) is halved / amplitude is 2 div / amplitude is 20 (mV) | B1 | **Note** this will also score the first B1 mark<br><br>**Examiner's Comments**<br><br>Most candidates understood that the new amplitude would be less than the original. Many thought it would be 1 / 16th of the original. The second mark was only gained by stronger candidates who explained why it would be 20 mV. |
| | | | **Total** | **6** | |
| 3<br>1 | | | (v = distance/time) $v = \frac{\lambda}{T}$<br><br>$f = \frac{1}{T}$ and v = fλ<br><br>**or**<br><br>There are $f$ wavelengths per unit time<br><br>v = distance travelled per unit time and v = f×$\lambda$ | M1<br><br>A1<br><br><br><br>M1<br><br>A1 | **Allow** '(distance travelled is) $\lambda$ in one period / $T$<br><br>**Not** $t$ for $T$<br><br>**Allow** '…in 1 s' instead of 'per unit time'<br><br>**Allow** $\lambda$ / 'waves'; **not** cycles / oscillations instead of wavelengths<br><br><u>**Examiner's Comments**</u><br><br>For maximum marks, it was important for candidates to clearly show all the steps leading to the wave equation. Supportive text always helps with the clarity of answers. The vast majority of the candidates produced flawless answers in terms of $\lambda$, $f$ and $T$. A significant number of candidates used $t$ or $d$, which made their working ambiguous. Some tried their luck with 4.0 s from **Fig. 16.1**, which led to no marks.<br><br>The exemplar 3 below shows a model response supported by equations and text and exemplar 4 shows that even top end candidates make mistakes.<br><br>**Exemplar 3**<br><br><br>A progressive wave has wavelength λ, frequency f and period T.<br>Show that the speed v of the wave is given by the equation v = fλ.<br>distance travelled in one period = λ<br>time = T<br>∴ speed of wave = distance/time = λ/T<br>T = 1/f so f = 1/T speed, v = fλ.<br>[2]<br><br>This is a model response for a show-type question. The text provides continuity and supports the derivation of the wave equation. A perfect solution. |

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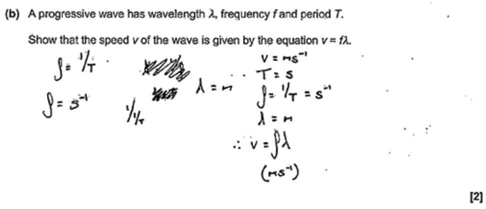
| | | | | | **Exemplar 4**<br><br>(b) A progressive wave has wavelength λ, frequency *f* and period *T*.<br>Show that the speed *v* of the wave is given by the equation *v* = *f*λ.<br>f = 1/T   f = s⁻¹   λ = m   v = ms⁻¹   T = s   f = 1/T = s⁻¹   λ = m   ∴ v = fλ (ms⁻¹)<br>[2]<br><br>This was a high scoring candidate overall who misunderstood the question here. The focus is on S.I. units of the various quantities and not on a derivation of $v = f\lambda$ from first principles. |
| | | | **Total** | **2** | |
| 3<br>2 | | | Use a polaroid / polarising filter<br><br>Rotation will change intensity | B1B1 | **Allow** brightness / light<br><br>**<u>Examiner's Comments</u>**<br><br>Most candidates scored well deserved 2 marks here for opting to use a polarising filter and rotating it to see variation in the intensity of the transmitted light. A small number of candidates chose the wrong equipment – the most common of these were diffraction grating, a single slit and microwave receiver. |
| | | | **Total** | **2** | |
| 3<br>3 | | | Microwaves from **T** are transverse/polarised wtte<br><br>At 0° or 180° the grille blocks (all) the (polarised) waves <u>and</u> at 90° the grille allows all the microwaves to pass. | **B1**<br><br>**B1** | **Allow** E field perpendicular to direction of motion<br><br>**Allow** explanation in terms of $I = I_0 \cos^2 \theta$<br><br>**<u>Examiner's Comments</u>**<br><br>Candidates found this question difficult. Candidates often did not state that the microwaves were polarised or mistakenly thought that the grille caused the microwaves to become polarised.<br><br>Candidates also did not appear to read the question carefully often thinking that the detected signal varied from a maximum initially. Some candidates quoted $I = I_0 \cos^2 \theta$ to help explain their answer. |
| | | | **Total** | **2** | |
| 3<br>4 | | | *phase difference:*<br>difference in degrees / radians/angle between points on the same wave or (similar) points on two waves | **B1**<br><br>**B1** | **Note** must be a comparison between points / waves<br>**Allow** how far out of step / sync or leads / lags for difference<br><br>**Allow** constant / fixed phase relationship<br>**Ignore** 'the frequency / wavelength is the same'<br>**Not** the same phase difference |

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| | | | *coherence:*<br>constant / fixed phase difference | | **Not** zero phase difference<br><br>**Examiner's Comments**<br>Many candidates found it difficult to define phase difference although coherence was usually correctly defined. |
| | | | **Total** | **2** | |
| 3<br>5 | | | c = $f\lambda$ **or** $f = 3.0 \times 10^8 / 0.60$<br><br>$f = 5.0 \times 10^8$ (Hz) | C1<br><br>A1 | **Allow** $v = f\lambda$<br><br>**Allow** $5 \times 10^8$ |
| | | | **Total** | **2** | |
| 3<br>6 | | | The <u>period</u> is determined by counting squares / from timebase<br><br>The frequency $f$ is period$^{-1}$ | **B1**<br><br>**B1** | **Note**: Any reference to <u>wave**length**</u> will lose this mark<br>**Not** 'determine $T$'<br><br>**Allow** $f = 1/T$<br><br><u>**Examiner's Comments**</u><br><br>The modal mark here was one, mainly through quoting the equation frequency = period$^{-1}$. Most candidates were baffled with the oscilloscope and could not effectively communicate how the period was determined from the trace on the oscilloscope screen. A significant number of candidates mentioned *wavelength* of the trace instead of *period*. Unfortunately, this led many candidates to quote $v = f\lambda$ as the equation for determining the frequency $f$. |
| | | | **Total** | **2** | |
| 3<br>7 | | | Transverse: <u>vibrations / oscillations</u> are perpendicular / right angles to the direction of travel / energy transfer (AW)<br><br>Longitudinal: <u>vibrations / oscillations</u> are parallel to / in the same direction as the direction of travel / energy transfer (AW) | B1<br><br>B1 | **Allow** 1 mark for 'For one of the waves, the oscillations / vibrations are at right angles and for the other they are parallel to the direction of travel' (AW)<br><br>**Not** move for vibrations / oscillations<br>**Allow 1** mark for transverse (waves) can be polarised ORA<br><br>**Examiner's Comments**<br><br>The opening question was supposed to be accessible to all the candidates. A significant number of candidates did not gain credit because of vague terminology, with 'move' or 'travel' often used to mean two things at once or not giving sensible discrimination between the directions of oscillation and wave / energy travel. |
| | | | **Total** | **2** | |
| 3<br>8 | | | $v \propto f$ and since $v \propto \sqrt{T}$, therefore $f \propto \sqrt{T}$<br><br>frequency will increase by a factor of $\sqrt{1.14} = 1.068$, therefore increase = 6.8% | C1<br><br>A1 | |
| | | | **Total** | **2** | |

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| 39 | | | Any **two** from:<br><br>• Reflection<br>• Diffraction<br>• Interference / superposition | **B1 × 2** | **Allow** correct annotation of Fig. 19.1 for each effect<br><br>**Examiner's Comments**<br><br>Most candidates scored two marks for identifying any two from diffraction, superposition (or interference) and reflection. A few answers were spoilt by mentioning either *refraction* or *total internal reflection*. |
| | | | **Total** | **2** | |
| 40 | a | i | $F = QE = QV / d$ **or** $E$ = 5(.0) x $10^4$ ($Vm^{-1}$)<br><br>$F = 9.0 \times 10^{-9} \times 4000 / 8.0 \times 10^{-2}$ (= $4.5 \times 10^{-4}$ N) | C1<br><br>A1 | $F = 5.0 \times 10^4 \times 9.0 \times 10^{-9}$<br><br>**Examiner's Comments**<br><br>Many lower ability candidates did not appreciate the uniform nature of the electric field between the plates and attempted to use Coulomb's Law. |
| | | ii | weight; arrow vertically downwards<br><br>tension; arrow upwards in direction of string<br><br>electric (force); arrow horizontally to the <u>right</u> (not along dotted line) | B1 x 2 | All correct, 2 marks; 2 correct, 1 mark<br>1 mark maximum if more than 3 arrows are drawn<br>**Ignore** position of arrows<br><br>**Allow** W **or** 0.030(N) (**not** gravity or g)<br>**Allow** T<br>**Allow** F **or** E or $4.5 \times 10^{-4}$(N) or electrostatic<br>**Ignore** repulsion or attraction<br>**Not** electric field / electric field strength / electromagnetic<br><br>**Examiner's Comments**<br><br>Most candidates scored a mark for showing the weight and tension forces accurately. Only a small proportion labelled the electric force arrow correctly and drew it as clearly perpendicular to the plates.<br><br>**AfL**<br><br>Do not use the word 'gravity' in place of 'weight' |
| | | iii | $W x = F l$<br><br>$0.03\,x$<br><br>= $4.5 \times 10^{-4} \times 120$ **or** = $4.5 \times 10^{-4} \times 1.2$ | M1<br><br>M1<br><br>A0 | **Allow** any valid alternative approach e.g.<br>M1 deflection angle $\theta = 1°$<br>M1 x = 120sin$\theta$<br><br>1 mark for each side of the equation<br><br>**Examiner's Comments** |

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| | | | $x$ = 1.8 cm **or** $x$ = 0.018 m | | Although most candidates knew the principle of moments, many were unable to apply it correctly in this situation. More practice at this sort of question is recommended. |
| | b | | Electric force/field (strength) increases<br><br>Ball deflected further from vertical / moves to the right / touches negative plate<br><br>Ball acquires the charge of the (negative) plate when it touches<br><br>(Oscillates because) constantly repelled from (oppositely) charged plate | B1<br><br>B1<br><br>B1<br><br>B1 | Must be clear which force is increasing<br><br>Must have the idea of a repeating cycle<br><br>**<u>Examiner's Comments</u>**<br><br>The purpose of this question was to challenge the candidates to use their knowledge of electric fields in a novel practical situation. The word 'oscillate' confused many candidates, who tried to explain why the ball would perform simple harmonic motion. |
| | c | | $I = Qf$ **or** $Q = It$<br><br>$f = 3.2 \times 10^{-8}/9.0 \times 10^{-9} = 3.6$ (Hz) | C1<br><br>A1 | |
| | | | **Total** | **12** | |
| 4<br>1 | | | Laser / ray box **or** protractor mentioned<br><br>Ray diagram showing (incident) ray **within** the block, (refracted) ray along the straight edge of block **and** critical angle marked between the incident ray and the normal<br><br>(Refractive index determined using) $n = 1/\sin C$ | **B1**<br><br>**B1**<br><br>**B1** | **Not** 'ray of light' for laser / ray box<br><br>**Allow** $C$, critical angle, $\theta$ or $i$ for the angle marked between the incident ray and normal<br>**Note**: No labelling of rays or normal is required<br>**Ignore** direction of rays<br>**Ignore** any internally reflected ray<br>**Note** this mark is for the **ray diagram. Ignore** description, unless there are <u>multiple</u> refracted rays shown<br><br>**Allow** any subject and terms do not need to be defined<br>**Not** bald '$n_1\sin\theta_1 = n_2\sin\theta_2$'<br><br>**<u>Examiner's Comments</u>**<br><br>The range of marks was poor in this practical question on refraction and critical angle. Most candidates did score a mark for selecting the correct expression for critical angle and refractive index from the Data, Formulae and Relationships booklet. The ray diagram lacked clarity and often showed incorrect critical angle in the air, rather than within the block. There were many missed opportunities here. No credit could be given for generic PAG–type description involving a rectangular block and plotting sini against sinr graph. |
| | | | **Total** | **3** | |

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| 4<br>2 | | i | ($f = v/\lambda$) = $3.00 \times 10^8 \div 4.69 \times 10^{-7}$ (= $6.40 \times 10^{14}$ Hz) | B1 | $6.397 \times 10^{14}$ Hz |
| | | ii | $1.96 \times 10^8$ ($ms^{-1}$)<br>$3.07 \times 10^{-7}$ (m) | B1<br>B1 | **Allow** $3.06 \times 10^{-7}$ (m) (uses **(i)**)<br>**Not** ECF for incorrect speed |
| | | | **Total** | **3** | |
| 4<br>3 | a | i | The superposition of coherent waves | **B1** | **Not** 'combine / meet / interact' for 'superposition'<br>**Allow** 'superposition of waves with a constant phase difference (at the sources)'<br>**Allow** 'waves that superpose constructively / destructively'<br><br>**Examiner's Comments**<br>Most candidates gave vague answers for interference. Answers such as '*this is when waves interact or collide*' were prevalent. Interference is the superposition of coherent waves. |
| | | ii | path difference (is 4.5 cm, which) is $1.5\lambda$<br><br>Destructive interference occurs | **M1**<br><br>**A1** | **Allow** lengths are $5\lambda$ & $3.5\lambda$ **and** phase difference = $180^{(o)}$ or waves are in anti-phase<br>**Not** $\lambda/2$ out of phase<br>**Not** path difference is 1.5 cycles / periods / oscillations<br><br>**Examiner's Comments**<br>This was another question that favoured the top-end candidates. The question required a clear understanding of path difference. Credit could only be given if the distances of 10.5 cm and 15.0 cm were used to answer the question. Destructive interference occurred at **C** because the path difference is **1.5**$\lambda$. A significant number of candidates struggled to get their physics across. Path difference was confused with phase difference and '*cycles*' was used to imply wavelength. Many candidates incorrectly concluded that the path difference was **0.5**$\lambda$. Weaker candidates referred to *nodes* and *antinodes* in their descriptions. |
| | b | i | 4 (cm) | **B1** | **Examiner's Comments**<br>Almost all scripts had the correct answer of 4.0 cm for the wavelength. |
| | | ii | (As the wave spreads out the) amplitude decreases<br><br>intensity ∝ amplitude$^2$ **and** therefore intensity decreases | **M1**<br><br>**A1** | **Not** 'displacement'<br>**Not** '$A$ decreases'<br>**Ignore** 'energy is lost'<br><br>**Allow** $I \propto A^2$<br>**Note** Do not allow this mark if we also have $I \propto 1/x^2$ but **allow** this mark if we also have $I \times 1/x$<br><br>**Allow** 1 mark for:<br>**(**$I = P / A$) power is constant and as area increases the intensity decreases<br>**or**<br>intensity ∝ 1/area and as area increases the intensity decreases<br><br>**Examiner's Comments**<br>About half of the candidates scored one or more marks for their |

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| | | | | | explanations. A fair number of candidates realised that the amplitude decreased and this led to a decrease in intensity because *intensity* ∝ *amplitude*$^2$. No credit was given to candidates who stated that the *'intensity decreased because of the inverse square law'*. The intensity of circular waves spreading out on the surface of water does not obey this law. A significant number of candidates incorrectly stated that the *'intensity and power decreased because of heat losses or friction'*. |
| | | | **Total** | **6** | |
| 4<br>4 | a | i | 1.36<br><br>1.97 × $10^8$ | B1<br><br>B1 | **Not** 1.3 or 1.4<br><br>**Not** 1.9 or 2.0<br><br>**<u>Examiner's Comments</u>**<br><br>This question was generally well answered. Some lower ability candidates were careless in the calculation of the speed of light in glass and gave their answers as either 1.9 or 2.0 as opposed to 1.97. There were also some candidates who gave an answer of 4.56 × $10^8$ m $s^{-1}$ – this is where candidates should check the pattern in the table. |
| | | ii | $\left(\frac{5.2\times10^{-7}}{1.52}=\right)$ 3.4(2) × $10^{-7}$ (m) | B1 | **Allow** 3.41 × $10^{-7}$ (m)<br><br>**Not** ECF from (a)(i)<br><br>**<u>Examiner's Comments</u>**<br><br>Surprisingly, this question did not score highly – many candidates did not realise that the wavelength of light in the glass would be the wavelength of light in air divided by the refractive index of glass. |
| | b | i | $\sin\theta = \frac{\sin 37}{1.52} (= 0.39593)$<br><br>$\theta$ = 23(.3)° | C1<br><br>A1 | **<u>Examiner's Comments</u>**<br><br>Many candidates correctly applied Snell's law. Common mistakes were either using the wrong refractive index or inverting the answer. |
| | | ii | Ray in glass bends towards normal and ray in ethanol bends away from normal but at a smaller angle than 37°<br><br>Rays are straight by eye | B1 | **Note** Ray should not be parallel to incoming ray.<br><br>**Not** angle of refraction is zero in glass<br><br>**<u>Examiner's Comments</u>**<br><br>This question required candidates to apply the previous answers to this question to draw an appropriate ray diagram. Candidates do need to use a ruler. A common error was for the emergent ray in the ethanol to be parallel to the incident ray in the air. This question required candidates to think through their diagram stage by stage using information from the previous part and the table given earlier in the question.<br><br>**Exemplar 8** |

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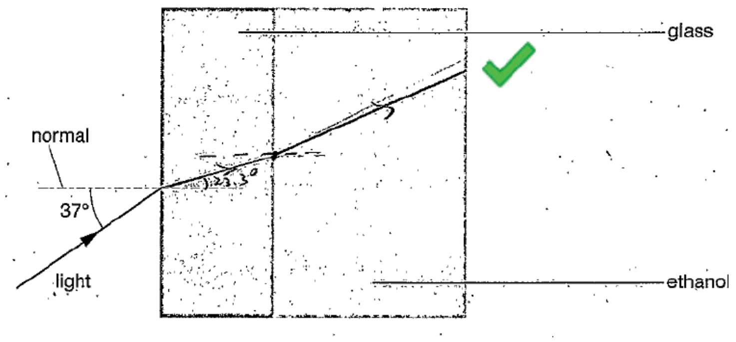
| | | | | | <br>This candidate has used a ruler and drawn straight rays. The candidate has marked on the normal and indicated the angle of refraction in the glass. It is clear that the ray in the ethanol is not parallel to the original ray. |
| | | | **Total** | **6** | |
| 4<br>5 | | | Speed / $v$ (of the progressive wave) is the same<br><br>Wavelength / $\lambda$ decreases as frequency / $f$ increases<br><br>length = $\lambda/2$ (for the first harmonic), length = $\lambda$ (for the second harmonic) and length = $3\lambda/2$ (for the third harmonic) | **B1**<br><br>**B1**<br><br>**B1** | **Allow** $f \propto 1/\lambda$ or $\lambda$ is halved when $f$ is doubled (AW)<br><br>**Allow** $L$ for length<br>**Allow** $\lambda = 2L / n$ ($n$ is 1, 2 and 3)<br>**Not** just $\lambda/2$, $\lambda$ and $3\lambda/2$ next to the patterns<br><br>**Examiner's Comments**<br>Full marks were rarely scored but many top-end candidates did manage to score two marks for recognising that the wavelength was inversely proportional to frequency and that the speed of the progressive wave was constant. A significant number of candidates recognised that the separation between adjacent nodes was half a wavelength, but then spoilt their answers by mentioning *'wavelength = 0.5λ for the first harmonic and wavelength = 1.5λ for the third harmonic'*. The answers from weaker candidates were confused with statements such as '20 Hz = 0.5λ'. |
| | | | **Total** | **3** | |
| 4<br>6 | | | in time $t_o$ car moves $vt_o$ | B1 | |
| | | | path lengths travelled by the two pulses differ by $c(t_o – t)$ | M1 | justified e.g. best solved by imagining first pulse takes time $T_o$ and second time $T$ and then $T_o – T = t_o$ |
| | | | but this is twice the distance the car has moved as it is a reflected signal | A1 | – t and / or drawing a space diagram. |
| | | | so $2vt_o = c(t_o − t)$. | A0 | |
| | | | **Total** | **3** | |
| 4<br>7 | | i | <u>Vibrations</u> or <u>oscillations</u> parallel to direction of travel of the wave / direction of energy transfer | B1 | |

| | | | | | |
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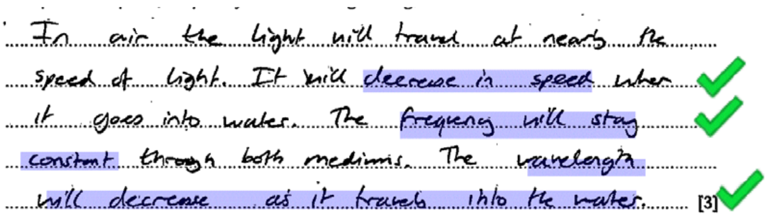
| | | ii | Amplitude of 2 cm (in each direction)<br><br>Sinusoidal shape (by eye) with period of 4 cm – at least two waves | B1<br><br>B1 | Check peak, equilibrium and trough positions<br><br>**<u>Examiner's Comments</u>**<br>In this question (a)(ii), candidates were required to sketch the trace. While perfect drawings are not expected, since the grid is given, candidates should try to use it effectively. The amplitude should be two squares above and two squares below for the peaks and troughs respectively. Similarly, for the period (4cm) using the grid, candidates should be able to make sure that the drawing is consistent at the peak, trough and zero lines. |
| | | | **Total** | **3** | |
| 4 8 | | | Speed of light is less in water (ORA)<br><br>Frequency is the same (in both)<br><br>Wavelength is smaller in water (ORA) | **B1**<br><br>**B1**<br><br>**B1** | **Allow** calculated values for air **and** water<br>**Allow** speed decreases (from air to water)<br>**Not** $v$ or $c$<br><br>**Allow** $f$ is the same<br><br>**Allow** wavelength / $\lambda$ decreases (from air to water)<br><br>**<u>Examiner's Comments</u>**<br><br>Most candidates gained two or more marks. Many candidates were aware that the speed of light was less in water than in air. A significant number of candidates also knew that the frequency of light remains constant and successfully argued the fate of the wavelength using the wave equation $v = f\lambda$.<br><br>**Exemplar 12**<br><br>In air the light will travel at nearly the speed of light. It will decrease in speed when it goes into water. The frequency will stay constant through both mediums. The wavelength will decrease as it travels into the water. [3]<br>This exemplar illustrates a flawless answer from a top–end candidate. It had all the main ingredients for scoring 3 marks. The answers matched well with the marking points – the examiner had no issues with following the text. |
| | | | **Total** | **3** | |
| 4 9 | | | λ / 2 = 0.54 / 3 = 0.18 m | C1 | |
| | | | λ = 0.18 × 2 = 0.36 (m) | C1 | |
| | | | $v$ = 60 × 0.36; speed = 21.6 m s$^{-1}$ ≈ 22 (m s$^{-1}$) | A1 | |
| | | | **Total** | **3** | |

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| 50 | | | wavelength = 60 (cm) | C1 | **Ignore** POT |
| | | | $v$ = 0.30/2.5 × $10^{-3}$ = 120 (m $s^{-1}$) | C1 | |
| | | | $f$ = 120/0.60 = 200 (Hz) | A1 | Possible ECF from incorrect value of speed $v$ |
| | | | **Total** | **3** | |
| 51 | | i | ($\lambda = \frac{3.00 \times 10^8}{11 \times 10^9}$)<br>$\lambda$ = 0.027 (m) | **B1** | **Note** answer to 3 SF is 0.0273 (m)<br>**Possible** SF penalty for 0.03 (m) |
| | | ii | Diffraction / spreading of the waves (occur at the narrow slit.)<br>This is because the wavelength is similar / comparable to the width / size / length of the slit (ORA) | **M1**<br>**A1** | **Allow** 'wavelength is same as the gap (size)' AW |
| | | | **Total** | **3** | |
| 52 | | i | period determined <u>using timebase</u><br>frequency = 1 / period | B1<br>B1 | **Allow** one mark for $f$ = 1 / $T$ without $T$ being defined |
| | | ii | $v = 2.1 \times 10^3 \times 0.16$<br>340 (m $s^{-1}$) | C1<br>A1 | **Allow ECF** from **(b)(iii)**<br>336 (3sf)<br>**Allow** one mark for 0.336 or 0.34 |
| | | | **Total** | **4** | |
| 53 | | | (intensity $I = I_0 e^{-\mu x}$) = 4.6 × $10^3$ × $e^{-0.85 \times 2.1}$<br>Either: (power =) 4.6 × $10^3$ × $e^{-0.85 \times 2.1}$ × 3.4 × $10^{-4}$<br>Or (energy per unit area =) 4.6 × $10^3$ × $e^{-0.85 \times 2.1}$ × 30<br>energy = 4.6 × $10^3$ × $e^{-0.85 \times 2.1}$ × 3.4 × $10^{-4}$ × 30<br>energy = 7.9 (J) | C1<br>C1<br>C1<br>A1 | intensity = 772 (W $m^{-2}$)<br>power = 0.262 (W)<br>energy per unit area = 23160 J $m^{-2}$<br>energy at surface = 47 (J) 2 marks<br>**<u>Examiner's Comments</u>**<br>There were many routes to a final answer in this question. Those candidates who set out their working carefully, used letters to represent the calculated quantity, and set this out in several stages tended to be the most successful. Some calculated the energy at the surface before going on to apply the attenuation formula, and others carried out the attenuation on the intensity. Each method can be credited at various stages, but it is important that a clear structure is shown. Many candidates attempted to change $cm^{-1}$ to $m^{-1}$ by dividing by 100, whereas the better candidates appreciated that the units of distance and attenuation constant would cancel in the exponent. Several candidates used the incorrect formula energy = power / time which can be a |

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| | | | | | common misconception. The correct formula is in the data booklet if required. |
| | | | **Total** | **4** | |
| 5<br>4 | | | the (sound) wave reflects at the water (surface)<br><br>reflected wave interferes/superposes with the incident wave<br><br>to produce a (resultant) wave with a node at the water surface <u>and</u> an antinode at the top of the tube<br><br>$l = \lambda/4$ | B1<br><br>B1<br><br>B1<br><br>B1 | **Allow** the (two) waves interfere/superpose<br>**Do not allow** interact/combine |
| | | | **Total** | **4** | |
| 5<br>5 | | i | It is longitudinal | B1 | |
| | | ii | Loudspeaker, microphone / ear and slit<br><br>Sound spreads from the slit AW<br><br>Size of slit comparable to the wavelength (of sound) | B1<br>B1<br>B1 | **Allow** doorway for a slit / gap - receiver for microphone<br>**Not** diffraction (since it is in the stem of the question) |
| | | | **Total** | **4** | |
| 5<br>6 | | i | sensible diameter, e.g. 7 (mm)<br><br>(power = $4.8 \times 10^{-7} \times \pi \times (0.0035)^2$ )<br><br>power = $1.8 \times 10^{-11}$ (W) | C1<br><br><br>A1 | **Allow** 2 − 16 (mm)<br><br>**Not** $\pi d^2$; this is XP<br><br>**Note check for AE** (condone rounding error here)<br><br>Possible ECF for diameter outside the range 2 − 16 (mm)<br>**Allow** 1 SF answer here |
| | | ii | ($I \propto A^2$; intensity doubles)<br>$A = \sqrt{2} \times 7.8$ (or equivalent)<br>$A$ = 11 (nm) | C1<br>A1 | **Allow** the C1 mark for $4.8 (\times 10^{-7}) = k \times [7.8 \times (10^{-9})]^2$ |
| | | | **Total** | **4** | |
| 5<br>7 | | i | **A** and **B** move in opposite directions | B1 | **Allow A** is moving up and **B** is moving down (or vice versa)<br>**Allow** they have a phase difference of 180$^{(\circ)}$ or π (rad)<br>**Allow** they are in antiphase<br><br>**Examiner's Comments**<br><br>The majority of the candidates gave a good answer. Most realised that the particles at **A** and **B** will be moving in opposite directions or have a phase difference of 180°. |

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| | | ii | $\lambda$ = 0.80 (m)<br>$v = f\lambda$, $v$ = 75 × 0.80 | C1 | **Allow** 80 (cm) for this C1 mark |
| | | ii | $v$ = 60 (m s$^{-1}$)<br>absolute uncertainty = $\frac{2.0}{40} \times 60$ | A1 | **Allow** 1 mark for 30 (m s$^{-1}$) from the C1A1 marks; $\lambda$ = 0.40 m used |
| | | ii | absolute uncertainty = 3.0 (m s$^{-1}$) | A1 | **Note** 60 ± 3 (m s$^{-1}$) scores full marks<br>**Allow** 2 marks for 6000 ± 300 (m s$^{-1}$); $\lambda$ in cm (POT error)<br>**Allow** 2 marks for 30 ± 1.5 (m s$^{-1}$); $\lambda$ = 0.40 m used<br><br>**Examiner's Comments**<br><br>This was a notable success for the candidates; many correctly determined the wave speed to be 60 m s$^{-1}$. The absolute uncertainty of 3.0 m s$^{-1}$ was correctly calculated by most of the top-end candidates. The most frequent incorrect values for the uncertainty were 0.02 m s$^{-1}$ and 0.04 m s$^{-1}$. A significant number of the low-scoring candidates took the wavelength to be 0.40 m. This gave an answer of (30 ± 1.5) m s$^{-1}$. Examiners awarded two marks for such an answer. |
| | | | **Total** | **4** | |
| 58 | a | | There is no contact force between the astronaut and the (floor of the) space station (so no method of measuring / experiencing weight) | B1 | **Allow** astronaut and the space station have same acceleration (towards Earth) / floor is falling (beneath astronaut)<br><br>**Examiner's Comments**<br><br>**Misconception**<br><br>Experiencing weightlessness is not the same as being in freefall<br><br>There was a lack of understanding of the nature of feeling weightless. The sensation of 'weightlessness' is a lack of the physiological sensation of 'weight'. The skeletal and muscular systems are no longer in a state of stress. This sensation is caused by a lack of contact forces as a result of the ISS and the astronaut experiencing the same acceleration.<br><br>Common incorrect responses included:<br><br>• the astronaut is weightless because he is falling<br>• there is no resultant force on the astronaut<br>• gravity is too weak to have any effect on the astronaut<br>• the ISS orbits in a vacuum where there is no gravity. |
| | b | i | $M$ = 5.97 x 10$^{24}$(kg)<br>**or** ISS orbital radius $R$ = 6.78 x 10$^{6}$(m)<br>**or** $g \propto 1/r^2$<br><br>($gr^2$ = constant so) $g$ x (6.78 x 10$^{6}$)$^2$ = 9.81 x (6.37 x 10$^{6}$)$^2$<br><br>$g$ = 8.66 (N kg$^{-1}$) | C1<br><br>C1<br><br>A1 | **or** $g$ (= $GM/R^2$) = 6.67 x 10$^{-11}$ x 5.97 x 10$^{24}$ / (6.78 x 10$^{6}$)$^2$<br><br>**Allow** rounding of final answer to 2 SF i.e. 8.7 (N kg$^{-1}$)<br><br>**Examiner's Comments** |

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| | | | | | The simplest method here was to use the fact that $g$ is inversely proportional to $r^2$, so $gr^2$ = constant. If this was not used, a value for the mass of the Sun had to be calculated, which introduced a further step. Candidates who omitted this calculation and used a memorised value of the Sun's mass instead were unable to gain full marks, because they invariably knew it to 1 s.f. only, whereas 3 were required.<br><br>Errors occurred when candidates used the incorrect distance in the formula for $g$. Common errors included:<br><br>• forgetting to square the radius<br>• using the Earth's radius rather than the orbital radius of the satellite<br>• calculating ($6.37 \times 10^6 + 4.1 \times 10^5$) incorrectly. |
| | | ii | $2\pi r/T = v$ **or** $T = 2 \times 3.14 \times 6.78 \times 10^6 / 7.7 \times 10^3$<br><br>$T = 5.5 \times 10^3$ s (= 92 min) | M1<br><br>A1 | **ECF** incorrect value of $R$ from **b(i)** |
| | c | | $\frac{1}{2}Mc^2$ ($\frac{1}{2}N_Amc^2$) = $\frac{3}{2}RT$<br><br>$c^2 = 3 \times 8.31 \times 293 / 2.9 \times 10^{-2} = 2.52 \times 10^5$<br><br>$\sqrt{c^2}$ = 500 (m s$^{-1}$)<br><br>(= $7.7 \times 10^3$ / 15) | C1<br><br>C1<br><br>A1<br><br>A0 | **or** $\frac{1}{2}mc^2 = \frac{3}{2}kT$ **or** $c^2 = 3kT/m$<br><br>**or** $c^2 = 3 \times 1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 293/2.9 \times 10^{-2} = 2.52 \times 10^5$<br><br>**not** ($7.7 \times 10^3$ / 15) = 510 (m s$^{-1}$)<br><br>**<u>Examiner's Comments</u>**<br><br>The success in this question depended on understanding the meaning of the term $m$ in the formula $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ given in the Data, Formulae and Relationship booklet. A significant number of candidates took $m$ to be the mass of one mole (the molar mass, $M$) whereas $m$ is actually the mass of one molecule. Candidates who used the formula $\frac{1}{2}M\overline{c^2} = \frac{3}{2}RT$ were usually more successful because the molar mass had been given in the question stem. |
| | d | | power reaching cells (= $IA$) = $1.4 \times 10^3 \times 2500 = 3.5 \times 10^6$ W<br><br>power absorbed = $0.07 \times 3.5 \times 10^6 = 2.45 \times 10^5$ W<br><br>cells in Sun for (92 – 35 =) 57 minutes<br><br>average power = $57/92 \times 2.45 \times 10^5 = 1.5 \times 10^5$ (W) | C1<br><br>C1<br><br>C1<br><br>A1 | mark given for multiplication by 0.07 at any stage of calculation<br><br>(90 – 35 =) 55 minutes using $T$ = 90 minutes<br>**ECF** value of $T$ from **b(ii)**<br><br>$55/90 \times 2.45 \times 10^5 = 1.5 \times 10^5$ (W) using $T$ = 90 minutes<br><br>**<u>Examiner's Comments</u>**<br><br>Although this question looked daunting, it was actually quite linear and many candidates who attempted it were able to gain two or three marks even if they did not eventually get to the correct response. Candidates who set out their reasoning and working clearly were more liable to gain these compensatory marks. |
| | | | **Total** | **13** | |

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| 59 | a | | tube pushed into water by λ/2 | B1 | allow any statement about antinode needed at open end and node at water level. |
| | | | therefore $\lambda/2 = 0.506 - 0.170$ giving $\lambda = 0.672$ (m) | B1 | |
| | | | using $v = f\lambda$ | C1 | |
| | | | $v = 500 \times 0.672 = 336$ (m $s^{-1}$) | A1 | A solution worked to 2 SF will score a maximum of 3 marks. |
| | b | | smaller λ means smaller *l* to measure, so less accurate measurement. | B1 | |
| | | | added detail or expansion of argument. | B1 | |
| | c | | the wave reflected at the end of the pipe interferes / superposes with the incident wave. | B1 | |
| | | | to produce a resultant wave with nodes and antinodes. | B1 | |
| | | | both ends must be antinodes **or** the pipe must be nλ/2 in length for this to happen. | B1 | |
| | | | at **Q** air molecules oscillate | B1 | **allow** vibrate. |
| | | | with motion along the axis of the tube **or** with maximum amplitude. | B1 | |
| | | | at **P** no motion / nodal point. | B1 | |
| | | | **Total** | **12** | |
| 60 | | i | Bright fringes are due to constructive interference and the dark fringes are due to destructive interference. | B1 | |
| | | i | Path difference is *n*λ **or** phase difference is 0° at positions of bright fringes. | B1 | |
| | | i | Path difference is (*n* + ½)λ **or** phase difference is 180° at positions of dark fringes. | B1 | |
| | | ii | **A** emits shorter wavelength of light. Since $x = \frac{\lambda D}{a} \propto \lambda$, the separation between the adjacent fringes is smaller. | B1 | |
| | | iii | There is no interference of light from the two slits **or** the bands disappear **or** there is only diffraction from a single slit. | B1 | |
| | | | **Total** | **5** | |

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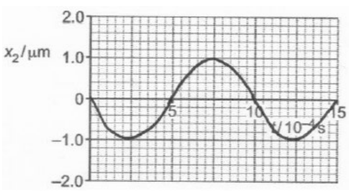
| 6<br>1 | | i | I = $I_0/r^2$ or I = $kr^{-2}$ | B1 | **allow** inverse square law statement |
| | | i | (k = 20) so I = $20/(0.25)^2$ = 20 × 16 = 320 | B1 | |
| | | ii | 640 | B1 | |
| | | iii | 640 = $20/r^2$ | C1 | **ecf(ii)1** |
| | | iii | so r = √(20/640) = 0.18 (m) | A1 | **accept** 0.177 (m) |
| | | | **Total** | **5** | |
| 6<br>2 | | i | Transverse wave | B1 | Full credit for clear, annotated diagram |
| | | i | Vibration in a fixed direction / plane | B1 | |
| | | ii | Rotate polaroid | B1 | |
| | | ii | Look for dim / bright light | B1 | |
| | | ii | Alternating every 90° | B1 | |
| | | | **Total** | **5** | |
| 6<br>3 | | i | Correct curve with amplitude of 1.0 µm and a phase difference of 180°<br> | **B1** | **Allow** a curve shown for a minimum of one period<br>**Allow** ± 0.2 µm for amplitude at any two points<br>**Not** 'triangular' profile for the curve |
| | | ii | The amplitude (at **P**) is smaller / < 3.0 (<m) / = 2.0 (<m)<br><br>intensity ∝ amplitude$^2$ (therefore the intensity is not the same) | **B1**<br><br>**B1** | **Not** displacement<br><br>**Allow** $I \propto A^2$, where $I$ = intensity and $A$ = amplitude<br><br>**Allow** 2 marks for 'intensity is $\left(\frac{2}{3}\right)^2 \times 100 = 44\%$ |
| | | iii | (The path difference is) 17 (cm) **or** half wavelength **or** $\lambda/2$.<br><br>Hence destructive (interference) | **M1**<br><br>**A1** | **Not** $(n + ½)\lambda$<br>**Not** <u>phase</u> difference is 17 (cm) **or** half wavelength **or** $\lambda/2$<br><br>**<u>Examiner's Comments</u>**<br><br>In **(b)(i)**, the majority of the candidates drew the correct curve of amplitude 1.0 µm and a phase difference of 180°.<br><br>Many candidates in **(b)(ii)** did not mention intensity at all in their description. Instead, the focus was on destructive interference without reference to their answer in **(b)(i)**. A very small proportion of candidates |

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| | | | | | did realise that the smaller amplitude of the signal at P meant the intensity was reduced because intensity is directly proportional to amplitude$^2$.<br><br>**(b)(iii)** was demanding. It was only the top–end candidates realising that the path difference of half a wavelength (17 cm) meant that the interference was destructive at point **Q**. Too many answers did not make any use of the information given in the question. Generic comments on interference prevented marks being gained in this question. |
| | | | **Total** | **5** | |
| 6<br>4 | | i | (surface area =) 4π × (1.4 × $10^9)^2$ **or** 2.46 × $10^{19}$ (m$^2$)<br>(intensity = $\frac{P}{4\pi r^2}$)<br>intensity = $\frac{2.7\times10^{27}}{4\pi\times(1.4\times10^9)^2}$<br>intensity = 1.1 × $10^8$ (W m$^{-2}$) | **C1**<br><br>**C1**<br><br>**A0** | **Allow** 2.5 × $10^{19}$ (m$^2$)<br>**Note**: Using π × (1.4 × $10^9)^2$ is wrong physics; hence no marks in this show question<br><br>**<u>Examiner's Comments</u>**<br><br>This was a demanding question designed for middle and top-end candidates. The radiant intensity is equal to the power transmitted per unit cross–sectional area. The area being that of a sphere of radius 1.4 × $10^9$ m. The equation 4πR$^2$ was appropriate here. The common errors, mainly from the low–scoring candidates, were using πR$^2$ and $\frac{4}{3}\pi R^3$. All the key steps in the calculations had to be structured well for |
| | | ii | $E = \frac{3.00\times10^8\times6.63\times10^{-34}}{5.0\times10^{-7}}$<br>$E$ = 4.0 × $10^{-19}$ (J) | **C1**<br><br>**A1** | **Note**: Answer to 3 SF is 3.98 × $10^{-19}$ (J)<br>**Allow** 4 × $10^{-19}$ (J) without any SF penalty<br><br>**<u>Examiner's Comments</u>**<br><br>Most candidates were familiar with the equation for the energy of the photon. Answers were generally well–structured and calculations were undertaken without much error in either rearranging the equation or powers of ten. The answer to two significant figures was 4.0 × $10^{-19}$ J, as in the general rule with such answers, 4 × $10^{-19}$ J was acceptable without any significant figure penalty. |
| | | iii | (number per second = $\frac{2.7\times10^{27}}{4.0\times10^{-19}}$)<br><br>number per second = 6.8 × $10^{45}$ (s$^{-1}$) | **B1** | Possible ECF from **(b)(ii)**<br><br>**<u>Examiner's Comments</u>**<br><br>This was a successful end for the top–end candidates, who correctly divided the total output power of Procyon of 2.7 × $10^{27}$ W by the energy of each photon from **(b)(ii)**. The two common errors were dividing the intensity by the photon energy and changing the photon energy from joule (J) to electron–volt (eV). |
| | | | **Total** | **5** | |

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| 6<br>5 | | i | ($v = f\lambda$)<br>$340 = 20 \times 10^3 \times \lambda$<br><br>wavelength = $1.7 \times 10^{-2}$ (m) | C1<br><br>A1 | **Allow** 1 mark for 17 (m); 20 Hz used<br><br>**<u>Examiner's Comments</u>**<br><br>This question should be a relatively simple introduction to the section, using a familiar formula to calculate a wavelength. Nearly all candidates were able to correctly make wavelength the subject of the equation, and the majority were able to select the correct frequency to use. Those that chose the other frequency could score 1 mark if correctly followed through. |
| | | ii | Loudspeaker and signal generator<br><br>Frequency increased until limit of hearing<br><br>frequency determined using $f = 1/T$ | B1<br><br>B1<br><br>B1 | **Allow** this mark for a labelled diagram<br><br>**Do not allow** t for time period<br><br>**<u>Examiner's Comments</u>**<br><br>This question was poorly answered in general; very few candidates appreciated the need to use a signal generator to produce varying frequencies and seemed to think that the oscilloscope would do this. Many candidates used diagrams (yet not always labelled) to show their apparatus. Although many did appreciate that the upper limit is reached when the hearing stops, few also then went on to say how the frequency could actually be determined. |
| | | | **Total** | **5** | |
| 6<br>6 | | | **Level 3 (5 – 6 marks)**<br>Response shows clear distinction between investigations; clear and correct reasoning is given for the situations which give maximum / minimum readings in <u>both</u> cases, including correct numerical values<br><br>*There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*<br><br>**Level 2 (3 – 4 marks)**<br>Response refers to both investigations; some reasoning is given for the situations which give maximum / minimum readings in <u>both</u> investigations, including some numerical values<br><br>*There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.*<br><br>**Level 1 (1 – 2 marks)**<br>Limited reasons are given for the | B1 x 6 | **Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2ˆ for 3 marks, etc.**<br><br>**Indicative scientific points may include:**<br><br>**explanation 1**<br><br>• receiver aerial vertical – electrons are driven (maximum distance) up and down along the length of the aerial because the oscillations (of the electric field) are vertical, causing maximum (a.c.) current<br>• receiver aerial horizontal – electrons are driven (minimum distance) across the aerial because the oscillations (of the electric field) are only in the vertical plane (no oscillation along the aerial to cause current), so zero / minimum current<br>• rotation of receiver aerial by ± 90° (or 90° and 270°) from vertical leads to zero current<br><br>**explanation 2**<br><br>• reflected wave superposes with incident wave at receiver aerial<br>• coherent waves as from same source<br>• constructive interference / waves in phase gives max current<br>• reflected wave has travelled nλ further, n = 0,1, etc<br>• so max current when plate is at λ/2, 2λ/2, etc from receiver aerial, i.e. 30, 60 cm<br>• destructive interference / waves 180° (π rad) out of phase gives zero current<br>• reflected wave has travelled (2n +1)λ/2 further, n = 0,1, etc |

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| | | | situations which give maximum / minimum readings in either investigation<br><br>*There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*<br><br>**0 marks**<br>*No response or no response worthy of credit.* | | • so zero current when plate is at λ/4, 3λ/4, etc from receiver aerial, i.e. 15, 45 cm<br>• reflected signal will be weaker the further it has to travel so no longer complete cancellation (ammeter reads close to zero)<br><br>**Note:** Give full credit to candidates who take the 180° (π rad) phase change on reflection into account, which gives max current at 15, 45 cm etc and zero current at 30, 60 cm etc.<br><br>**Examiner's Comments**<br><br>This was the second of the two LoR questions in this paper. It required knowledge of polarisation, superposition and interference. There is no one perfect model response but generally, for Level 3, candidates were required to give clear reasoning for the situations which gave both maximum and minimum readings in both investigations. Such candidates included correct numerical values in their responses (although 'half a wavelength' was acceptable in place of 30cm). Level 2 responses were sometimes incomplete (e.g. giving the maximum position but not the minimum position) or confused (e.g. the maximum and minimum positions were given but were the wrong way around). Level 1 responses came from candidates who misunderstood the physics of one of the situations, or who confused phase difference and path difference, or whose descriptions were generally too vague to gain much credit.<br><br>It may be helpful to point out that investigation **2** was not about the formation of a stationary wave; rather, it was about two overlapping coherent waves forming regions of constructive and destructive interference. A common misconception was that the maximum and minima signals were related to antinodes and nodes.<br><br>**Misconception**<br><br>A minimum or zero reading does not occur when two waves are merely out of phase. They must be *completely* out of phase. The best way to describe this is to say that they are **in antiphase**. |
| | | | **Total** | **6** | |
| 67 | a | i | (speed in material =) $\frac{3.0 \times 10^8}{1.20}$ **or** $2.5 \times 10^8$ ($ms^{-1}$)<br><br>($t_V$ =) $\frac{1.5 \times 10^{-6}}{3.0 \times 10^8}$ **or** $5.0 \times 10^{-15}$ (s)<br><br>($t_M$ =) $\frac{1.5 \times 10^{-6} \times 1.20}{3.0 \times 10^8}$ **or** $6.0 \times 10^{-15}$ (s)<br><br>$t = [6.0 – 5.0] \times 10^{-15} = 1.0 \times 10^{-15}$ (s) | C1<br><br>C1<br><br>C1<br><br>A0 | **Allow other correct methods**<br><br>**Note** omitting or incorrect use of 1.2 is XP<br><br>**Allow** 1 SF answer $5 \times 10^{-15}$<br><br>**Allow** 1 SF answer $6 \times 10^{-15}$<br>**Note** this also scores the first C1 mark<br>**Note** omitting or incorrect use of 1.2 is XP<br><br>**Examiner's Comments**<br><br>Generally, candidates answered this question extremely well and most scoring full marks |

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| | | | | | In **(c)(i)**, the solutions ranged from being well-structured to an assortment of equations and substitutions filling the entire answer space. Equations for refractive index and speed were easily used to show the answer to be 1.0 × $10^{-15}$ s.<br><br>In **(c)(ii)**, candidates either calculated the frequency of 5.0 × $10^{14}$ Hz and then used $T = f^1$ or calculated $T$ directly using $T = \frac{6.0 \times 10^{-7}}{3.0 \times 10^{8}}$ = 2.0 × $10^{-15}$ s.<br><br>**(c)(iii)** provided some discrimination with middle and top candidates getting the correct answer of 180°. As always, error carried forward (ECF) rules apply in calculations. This helped those candidates who got an incorrect answer of 2.4 × $10^{-15}$ s in **(c)(ii)** to score a mark for 150°.<br><br>**Misconception**<br><br>There were some missed opportunities, with some candidates making the following mistakes.<br><br>• In **(c)(i)** calculating the difference in the time for the two rays by halving the period of 2.0 × $10^{-15}$ s.<br>• In **(c)(ii)** using the wavelength in vacuum of 6.0 × $10^{-7}$ m but the incorrect speed of 2.5 × $10^{8}$ ms$^{-1}$ to calculate the period. This gave an answer of 2.4 × $10^{-15}$ s; examiners allowed 1 mark for this method.<br>• In **(c)(iii)**, a small number of candidates, mainly at the low-end, confused the symbol $\varphi$ for phase difference to be work function. This produced some bizarre answers. |
| | | ii | $(f =) \frac{3.0\times10^{8}}{6.0\times10^{-7}}$ **or** 5.0 × $10^{14}$ (Hz) **or** $(T =) \frac{6.0 \times 10^{-7}}{3.0 \times10^{8}}$<br><br>T = 2.0 × $10^{-15}$ (s) | C1<br><br>A1 | **Allow** 1 SF of 2 × $10^{-15}$<br>**Allow** 1 mark for 2.4 × $10^{-15}$ (s); 2.5 × $10^{8}$ ms$^{-1}$ used |
| | | iii | $\varphi$ = 180° | B1 | Possible ECF from **(i)** and **(ii)**<br>**Note** answer must be $\varphi$ = **(c)(i)** × 360°/**(c)(ii)**<br>**Not** an answer in rad, e.g. π rad |
| | b | | **Level 3 (5–6 marks)**<br>Clear description **and** clear analysis<br><br>*There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* | B1× 6 | Use level of response annotations in RM Assessor<br><br>**Indicative scientific points may include:**<br>**Description**<br><br>• Method for creating wave / pulse, e.g. lifting and releasing tray, dropping a ball into the water, ripple-tank arrangement, etc. (Details not expected)<br>• speed = distance ÷ time **or** $v = x \div t$ **or** $v = f\lambda$<br>• Measure distance travelled using a ruler |

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| | | | **Level 2 (3–4 marks)**<br>Clear description<br>**or**<br>Clear analysis<br>**or**<br>Some description **and** some analysis<br><br>*There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.*<br><br>**Level 1 (1–2 marks)**<br>Limited description<br>**or**<br>Limited analysis<br><br>*There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*<br><br>**0 marks**<br>No response or no response worthy of credit. | | • Use a stopwatch / timer/ video technique / strobe to measure time / frequency<br>• Measure the depth of water using a ruler etc<br>• Record / measure / determine *v* for different *d*<br>• Repeat to find average *v*<br><br>**Analysis**<br><br>• Plotting a graph, e.g. *v* against $\sqrt{d}$ **or** $v^2$ against *d* **or** lg*v* against lg*d* etc.<br>• Correct determination of *g* from straight-line graph<br>**or**<br>• Table with *v* and $\sqrt{d}$ **or** $v^2$ and *d*<br>• Correct calculation of average value of *g* from the table<br><br>**<u>Examiner's Comments</u>**<br><br>This level of response (LoR) question was designed to assess practical skills of planning, implementation, analysis and evaluation from module 1 of the specification, together with the mathematical skills of graphs from Section M3. The context of the question was waves and the relationship between wave speed *v* and depth *d* of the water.<br><br>A holistic approach to marking is used, with marks given according answers matching the descriptors for the various levels. There is no one perfect answer for this question, examiners were expecting an eclectic approach. The key things examiners were looking for were:<br><br>- A plausible technique for creating the waves on the surface of the water.<br><br>- Method for determining the speed of the waves.<br><br>- Instruments used for measurements.<br><br>- Techniques used to produce reliable results.<br><br>- The graph plotted, and how the acceleration of free fall *g* is determined from the data.<br><br>On occasions, the methods used for determining the speed of the waves and creating the waves were a bit creative, but perhaps plausible in the hands of very competent physicists. For examples, light-gates were often used to determine the speed of the waves. The intricacies of this method were often omitted, but given lots of time, the technique could be made to work. There were some interesting suggestions about using a motion-sensor above a floating ball to determine the frequency of the waves. Examiners were not looking for perfection. Most candidates either dropped objects into the water or struck the side of the tray to create the waves. The speed was often determined by dividing the distance travelled by the wave by the time it took to travel a known distance. |

Candidates either plotted $v^2$ against $d$ or $v$ against $\sqrt{d}$ to determine $g$. Across the ability range, the analysis sections of the answers were generally better than the descriptions.

The exemplar 5 shows a response that scored Level 3 (L3) and exemplar 6 shows a response that missed out on a top score because of lack of detail in the description.

**Exemplar 5**

* Fill the plastic tray with a supply of water, up to ~~depth of 30 cm~~ a shallow depth.
* Measure the depth of water using a ruler with a mm scale, this can be placed in the plastic tray. Record the depth reading.
* Using a ripple machine (a rod connected to a vibration generator) surface water waves can be produced by the repeated motion of the rod on the water.
* ~~Connect the vibration generator to~~ Adjust the frequency of the vibration generator until water waves are present on the surface of the water. These may be hard to spot at first.
* Using a ruler, measure the distance between the rod and the end of the tray, then, using a

Additional answer space if required.

stopwatch ~~record~~ measure the time taken for the wave from the rod to reach the end of the tray. Now, alter the depth at regular intervals.
* Calculate the speed using distance travelled / time.
* Calculate $v^2$ by squaring this answer.
* Plot a graph of $v^2$ against $d$ (depth of water) this should produce a straight line through the origin.

* Gradient of this line = g.

$\rightarrow v = \sqrt{gd}$

$v^2 = (g)d$

$y = (m)x$

This exemplar shows that examiners are not expecting perfection with the practical skills or the analysis. The description here is clear, as is the analysis. This response met all the requirements of a Level 3 score.

**Exemplar 6**

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| | | | | | Using the plastic tray, changing the depth of the water while not adjusting ~~[illegible]~~ oscillator the frequency driver of wave inducer. with keeping f constant ~~[illegible]~~ the wavespeed will change only based on depth. Measure wavespeed by measuring time for wave to travel full length of tray or a set distance. Using $v^2$ against d, change the depth to have a varied range of wave speed. using $v^2$ against d will result in the gradient of graph being equal to value of g. The relationship will be confirmed by a constant gradient through origin since g is a constant value. A mechanical driver would be preferred to keep the frequency constant, meaning the speed of water waves will only change because of depth of water.<br>Additional answer space if required.<br>Using $l = v$ and $10 \times 10^{-2} = d$ a value of 10 $N kg^{-1}$ can be calculated. Measure a range of values for depth with resulted speed of waves to plot data and graph<br><br>This exemplar shows a Level 2 response. You will notice that the description is not as robust at that shown in exemplar 5. The analysis in both is similar. There are small margins between the levels. |
| | | | **Total** | **12** | |
| 68 | a | i | 0.45 (m) | B1 | **Examiner's Comments**<br><br>This question was generally answered very well. Most candidates understood the definition of amplitude although, a number of candidates incorrectly stated 0.9 m |
| | | ii | 4.0 (m) | B1 | **Ignore** significant figures<br><br>**Examiner's Comments**<br><br>This question was generally answered very well with most candidates understanding the definition of wavelength. |
| | | iii | $\frac{0.5}{4}$ or $\frac{1}{8}$<br>$(\frac{0.5}{4} \times 2\pi =) \frac{\pi}{4}$ or 0.79 (rad) | C1<br>A1 | **Allow ECF** from (ii)<br><br>**Note** 0.785<br><br>**Examiner's Comments**<br><br>The majority of candidates did not gain credit on this question.<br><br>Successful candidates clearly showed their working. Some candidates were not sure how to change a fraction of a wavelength into a phase difference in radians. |
| | | iv | $0.45^2$ or $0.15^2$ or 0.2025 or 0.0225<br><br>9 | C1<br>A1 | **Allow ECF** from (i)<br><br>**Allow** one significant figure<br><br>**Examiner's Comments**<br><br>Candidates found this question challenging. They often did not realise that the intensity is proportional to the amplitude squared. It was helpful where candidates showed their working. |

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| | b | | **Level 3 (5–6 marks)**<br>Clear procedure, measurements and analysis<br><br>*There is a well-developed line of reasoning which is clear* ***and*** *logically structured. The information presented is relevant and substantiated.*<br><br>**Level 2 (3–4 marks)**<br>Some procedure, some measurements **and** some analysis.<br><br>*There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.*<br><br>**Level 1 (1–2 marks)**<br>Limited procedure, limited measurements **and** limited analysis<br><br>*There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*<br><br>**0 marks**<br>No response or no response worthy of credit. | B1 x 6 | **Indicative scientific points may include:**<br>**Procedure**<br><br>• labelled diagram<br>• two loudspeakers OR loudspeaker and double slit<br>• signal generator connected to loudspeaker(s)<br>• microphone and oscilloscope/sound sensor<br>• microphone and oscilloscope/sound sensor moved between loudspeakers<br>• safety precaution (ear defenders)<br>• method to avoid reflections of sound<br>• change frequency and repeat measurements for x<br>• $D >> a$<br><br>**Measurements**<br><br>• frequency determined from oscilloscope/ reading from signal generator<br>• additional detail from use of oscilloscope e.g. time-base to determine period and $f = 1/T$<br>• use of rule(r) to measure distances *a, D* and *x*<br>• measures over several maxima/minima<br><br>**Analysis**<br><br>• rearrangement of equation for v or into $y=mx$<br>• plot a graph of $x$ against $1/f$ or equivalent<br>• straight line through origin confirms relationship<br>• gradient = $vD / a$<br>• $v = \frac{a \times \text{gradient}}{D}$ .<br><br>**<u>Examiner's Comments</u>**<br><br>This question is assessing candidates' abilities to plan an investigation.<br><br>Some candidates assumed that this was two-source light interference and discussed the use of lasers, etc. It is important that candidates answer the question set.<br><br>The stem of the question indicates that a suitable diagram should be drawn. Many candidates did not label their diagrams, or the diagrams were not workable. Higher ability candidates indicated two loudspeakers connected to a signal generator and a microphone connected to an oscilloscope to detect the resultant signal.<br><br>When answering planning questions, candidates should identify the measurements that need to be taken and indicate appropriate measuring instruments. In this experiment, candidates were able to explain how the frequency of the sound could be determined using an oscilloscope as well as how distances could be measured.<br><br>Candidates also needed to explain how the data would be analysed. Higher ability candidates suggested the plotting of an appropriate graph |

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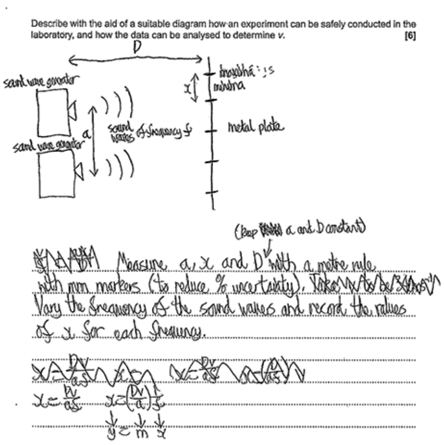
| | | | | | and explained how the speed of sound could be determined from the gradient.<br><br>**AfL**<br><br>Practical skills guidance can be found in the Practical Skills Handbook available on the OCR website:<br><br>https:/www.ocr.org.uk/Images/295483-practical-skills-handbook.pdf<br><br>**Exemplar 7**<br><br><br>The candidate's is answering the question as shown by the diagram containing two speakers. There is an indication of how the distances may be measured and that the frequency is going to be varied. The candidate also indicated how the results would be analysed graphically and how the speed of sound could be determined from the gradient of the plotted graph. This is a Level 2 response worth four marks since there is a line of reasoning and the information provided is relevant.<br><br>To improve this response, the candidate could have included a signal generator and also a means of detecting the sound at the distance indicated. There should also have been detail on how the frequency was determined. |
| | | | **Total** | **12** | |
| 6<br>9 | | i | (refraction index) = speed of light in vacuum + speed of light in material | B1 | **Note** light must be mentioned at least once<br>**Allow** n = c / v if all terms defined<br>**Allow** ration of speed of light in vacuum to speed of light in material<br>**NOT** speed of light in air for c |

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| | | ii | Frequency (of light) is the same (in **A** and **B**)<br>1 (Light travels) slower in **B** **or** $v_B = 0.77\ v_A$ ORA<br>$v = f\lambda$ <u>and</u> $\lambda_B < \lambda_A$<br>2 $\sin 60° = 1.3 \times \sin\theta$<br>$\theta = 42$ (°)<br>*(No total internal reflection)*<br>3 *Internal reflection / critical angle can only occur for light travelling from* **B** *to* **A** *AW* | B1<br>B1<br>B1<br>C1<br>A1<br>B1 | **Allow** *f* for frequency<br>**Allow** *v* directly proportional to *k*<br>***Allow*** *TIR can only occur for light entering an optically less dense material / lower refractive index ORA* **Not** $\theta < \phi$ |
| | | | **Total** | **7** | |
| 7 0 | | i | Straight-line of best fit drawn<br>gradient = 170 (Hz m) | B1<br>B1 | **Allow** value in range 160.0 to 180.0<br>**<u>Examiner's Comments</u>**<br>The straight-lines of best fit were generally acceptable. A small number of candidates drew the lines using very thick or indistinct pencil leads. Large triangles were often used to determine the gradient of the lines. Only a very small number of candidates, mainly at the lower quartile, made errors with powers of ten and got an answer of 0.17 instead of 170. |
| | | ii | $v = f\lambda$ or $\lambda = 2L$ **or** $v = 2fL$ (Any subject)<br>Clear steps leading to gradient $= \frac{v}{2}$ using $y = mx$ | C1<br>A1 | Allow separation between adjacent nodes $= \frac{\lambda}{2}$<br>**Allow** gradient = $f \div (\lambda/2)^{-1} = f\lambda/2 = v/2$<br>**<u>Examiner's Comments</u>**<br>Most candidates scored 1 mark for either quoting the wave equation v = fλ or the wavelength being twice inter-nodal distance *L*. The analysis leading to the gradient = *v*/2 proved to be quite demanding for most of the candidates. The most frequent incorrect reasoning was that speed v was divided by 2 because the sound waves are reflected from the wall, and they had to travel twice the distance there and back. Only the most able of the candidates scored full marks. |
| | | iii | $v = 2 \times 170$<br>v = 340 (m $s^{-1}$) | B1 | Possible ECF from **(b)(i)**<br>**<u>Examiner's Comments</u>**<br>Almost all candidates picked up 1 mark for multiplying their answer from **(b)(i)** by 2. This included those who also got an answer such as 0.17 in (b)(i). Error carried forward (ECF) rules were applied even when the speed of sound looked unrealistic. |
| | | i v | | | **Allow** other sensible suggestions<br>**Allow** increase wavelength / $\lambda$ (ORA) |

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| | | | Decrease frequency / *f* (ORA)<br><br>*L* / *λ* increases (so, smaller % uncertainty) (ORA)<br><br>**or**<br><br>Measure distance between several nodes / antinodes<br>Distance measured is larger (so, smaller % uncertainty)<br><br>**or**<br><br>Use a small(er) microphone<br><br>Easier to locate position of node / antinode (so, smaller % uncertainty) | M1<br><br>A1<br><br><br><br>M1<br><br>A1<br><br><br><br>M1<br><br>A1 | **Allow** L increases (so, smaller % uncertainty) (ORA)<br><br>**Allow** reduce reflection of sound (other than from the wall)<br><br>**Examiner's Comments**<br><br>This was a low-scoring question, with many candidates focussing on averaging results. Only a small number of candidates appreciated that lower frequency would give longer inter-nodal distance L, and this resulted in smaller percentage uncertainty. |
| | | | **Total** | **7** | |
| 7<br>1 | | i | sin **or** cos wave with 1.5 wavelengths (between **C** and **R)**<br>y-axis showing scale, i.e. (amplitude)<br>2.(0) × $10^{-6}$ (m)<br>correct scale on x-axis showing λ = 0.2 (m)<br>**X** and **Y** labelled at adjacent intercepts on x-axis | **B1**<br><br>**B1**<br><br>**B1**<br>**B1** | unit must be present, e.g $10^{-6}$ m<br><br>**NOT** if axis labelled time<br><br>**Examiner's Comments**<br>Most candidates correctly labelled the scale on the displacement axis of the sinusoidal graph that they drew. The points where the air particles were moving the fastest were also well known. Fewer labelled *distance* on the x-axis, many incorrectly writing *time.* Only the better candidates marked the correct scale on this axis and very few indicated that there were 1.5 wavelengths between the points **C** and **R.** |
| | | ii | **1** v = Aω **or** 2πfA<br>v = (2 × $10^{-6}$ × 2 × 3.14 × 1.7 × $10^3$ =)<br>2.1 × $10^{-2}$ (m $s^{-1}$.)<br><br>**2** ½M$v^2$ = 3/2 RT and T = 290<br>v = √(3 × 8.31 × 290 / 0.029)<br>v = 5(.0) × $10^2$ (m $s^{-1}$.) | **C1**<br>**A1**<br><br><br>**C1**<br><br>**A1** | **or** ½m$v^2$ = 3/2 kT so $v^2$ = 3 (k / m) 290<br><br>**N.B. remember to record a mark out of 4 here**<br><br>**Examiner's Comments**<br>Answers were generally well structured into two sections, one for each experiment. A few candidates thought they could measure the wavelength on the oscilloscope screen. In experiment (a) most understood that the phase difference between the two oscillations at the microphone changed as one speaker was moved away. Explanations often muddled *path* and *phase* difference or referred to *nodes* and *antinodes* detected by the microphone. Some candidates misinterpreted |

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| | | | | | the experiment moving the microphone to detect interference fringes, allowing the double slits formula to be used to find the wavelength. Others thought that Doppler shift was applicable.<br>For experiment (b) many candidates used *maxima* and *minima* in place of *antinodes* and *nodes* although most recognised this to be a *standing* wave situation. Quite a few candidates ignored the instruction about reducing the uncertainty. The best candidates suggested reducing the frequency to reduce the percentage uncertainty in the wavelength measurement. |
| | | | **Total** | **8** | |
| 7<br>2 | | i | reflected signals from M (amplitude a) and H (amplitude A) are added at the receiver | B1 | **accept** interfere. |
| | | i | path difference between moving reflected signal and fixed reflected signal varies between 0 and λ | B1 | **or** phase difference between the two received signals varies between 0 and 2π |
| | | i | sum of the displacements at the receiver varies between A + a and A – a | B1 | |
| | | i | any 3 from<br>• signal from M is attenuated because travels further;<br>• absorbed passing twice through H or some reflected at the back of H<br>• signal from H will increase as H moves towards the detector<br>• if A is much greater than a then variation will be difficult to detect. | B1 | allow absorbed or similar word for attenuated. |
| | | i | | | allow full credit for discussion in terms of $(A^2 – a^2)/(A^2 + a^2)$. |
| | | ii | detected signal varies between max and min for λ/4(= 7.0 mm) as path difference is λ/2 | B1 | |
| | | ii | every λ/2 (14 mm) moved, the signal goes through one cycle | B1 | |
| | | ii | so for 200 Hz must go through 100 λ in 1 s = 2.8 (m $s^{-1}$). | B1 | |
| | | | **Total** | **9** | |
| 7<br>3 | | i | Place a microphone close to loudspeaker and connect it to the oscilloscope. | B1 | **Allow** ‘connect oscilloscope to the signal generator (which is connected to the loudspeaker)’ |

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| | | i | Measure the number of divisions between neighbouring peaks of the signal. (AW) | B1 | |
| | | i | The separation between the neighbouring peaks should be 3.6 divisions. | B1 | |
| | | ii | The sound is diffracted at each slit. | B1 | |
| | | ii | The diffracted waves interfere in the space beyond the slits. | B1 | |
| | | ii | There is loud sound / maxima / constructive interference when phase difference is zero or when path difference *n*λ. | B1 | |
| | | ii | There is quiet sound / minima / destructive interference when phase difference is 180° or when path difference is (*n* + ½)λ. | B1 | |
| | | iii | $x = 2 \times 0.75$ (= 1.5 m) | C1 | |
| | | iii | $\lambda = \frac{0.40 \times 1.5}{5.0}$ | C1 | |
| | | iii | $\lambda = 0.12$ (m) | C1 | |
| | | iv | $v = 2800 \times 0.12$<br>$v = 340$ (m s$^{-1}$) | B1 | Possible ecf from **(iii)** |
| | | v | Position does not depend on intensity, hence no change. | B1 | |
| | | v | Intensity decreases | M1 | |
| | | v | by a factor of 4. | A1 | |
| | | | **Total** | **14** | |