CAMBRIDGE
International Education

Cambridge International AS & A Level

PHYSICS **9702/44**

Paper 4 A Level Structured Questions **May/June 2026**

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme contains the instructions and marking guidance that our examiners used to mark candidate responses for this component.

Before they start marking, examiners complete a standardisation process. They review a range of candidate responses and discuss the mark scheme in detail to agree which answers can and cannot be accepted. Examiners award marks where it is clear that candidate responses have met the requirements of the mark scheme. These requirements may vary between different components or different versions of the same component, depending on the exact requirements of the question and the candidate responses seen during the standardisation process.

Sometimes, our mark schemes may allow marks to be awarded to responses which contain elements that are factually incorrect or for content not covered by the syllabus. We do this in response to the demands of a specific question to support candidates and make sure that our assessments are fair. However, these allowances should not be used as a guide for teaching and learning.

We cannot discuss the mark scheme with schools, and we recommend that schools read the mark scheme together with the assessment material and the Principal Examiner Report for Teachers.

This document consists of **21** printed pages.

[Turn over

General marking principles

All examiners must apply these marking principles when marking candidate responses.

1	Examiners must award marks for each response in line with: • the specific **content** defined in the mark scheme • the specific **skills** defined in the mark scheme or in the level descriptions • the **standard of response** required as exemplified by the standardisation scripts.
2	Examiners must award **whole marks** (not half marks, or other fractions).
3	Examiners must award marks **positively**. This means that: • marks are not deducted for errors or omissions • marks are awarded for correct/valid answers as defined in the mark scheme and also for **other valid answers** which go beyond the scope of the syllabus and mark scheme referring to your team leader as appropriate • the quality of spelling, punctuation and grammar are judged **only** when the mark scheme indicates that these features are **specifically assessed** in the question. However, the meaning of all responses must be unambiguous.
4	Examiners must **consistently** apply the requirements of the mark scheme and any rules for what to do when candidates have not followed instructions correctly.
5	Examiners must use the **full range of marks** defined in the mark scheme, unless limited by the quality of the candidate responses seen.
6	Examiners must award marks according to the mark scheme and **must not** award marks with grade thresholds or grade descriptions in mind.

Science-Specific Marking Principles

1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
3	Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
4	The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
5	‘List rule’ guidance For questions that require ***n*** responses (e.g. State **two** reasons …): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked *ignore* in the mark scheme should not count towards ***n***. • Incorrect responses should not be awarded credit but will still count towards ***n***. • Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response. • Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

Annotations

Annotation	Meaning
AE	arithmetic error
BOD	benefit of the doubt given
CON	contradiction in response, mark not awarded
	correct point or mark awarded
ECF	error carried forward applied
SF	error in number of significant figures
I	incorrect or insufficient point ignored while marking the rest of the response
XP	incorrect physics
	incorrect point or mark not awarded
^	information missing or insufficient for credit

Annotation	Meaning
MO	mandatory mark not awarded
SEEN	point has been noted, but no credit has been given or blank page seen
POT	power of ten error
TE	transcription error

Abbreviations

/	Alternative and acceptable answers for the same marking point.
( )	Bracketed content indicates words which do not need to be explicitly seen to gain credit but which indicate the **context** for an answer. The context does not need to be seen but if a context is given that is incorrect then the mark should not be awarded.
___	Underlined content must be present in answer to award the mark. This means either the exact word or another word that has the same technical meaning.
AFC	Automatic full credit (**A** and **C** marks) for correct numerical answer (see science-specific marking principle 6).

Mark categories

B marks	These are independent marks, which do not depend on other marks. For a **B** mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer.
M marks	These are mandatory marks upon which **A** marks later depend. For an **M** mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer. If a candidate is not awarded an **M** mark, then the later **A** mark cannot be awarded either.
C marks	These are compensatory marks which can be awarded even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known them. For example, if an equation carries a **C** mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C** mark is awarded. If a correct answer is given to a numerical question, all of the preceding **C** marks are awarded automatically. It is only necessary to consider each of the **C** marks in turn when the numerical answer is not correct.
A marks	These are answer marks. They may depend on an **M** mark or allow a **C** mark to be awarded by implication.

Question	Answer	Marks	Guidance
1(a)	(electric) force is (directly) proportional to product of charges	**B1**	**Ignore** any symbols unless they are defined.
	(electric) force (between point charges) is inversely proportional to the square of their separation	**B1**	**Ignore** any symbols unless they are defined. **Do not allow** just 'distance' for 'separation' unless it is clear that the distance is between the charges. **Do not allow** 'radius' for 'separation'.
1(b)(i)	$(-)\ (1.09 \times 10^{-18}) = (-)\ (1.60 \times 10^{-19})^2 / (4\pi \times 8.85 \times 10^{-12} \times R)$ leading to $R = 2.11 \times 10^{-10}$ m	**A1**	**Allow** '8.99×10^{9}' for '$1 / (4\pi \times 8.85 \times 10^{-12})$' Full substitution and answer needed. **Ignore** signs of the energies. Unit not needed but any unit given must be correct.
1(b)(ii)	$F = (1.60 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (2.11 \times 10^{-10})^2]$ $= 5.17 \times 10^{-9}$ N	**A1**	No ECF from **1(b)(i)**. **Allow** 8.99×10^{9} for $1 / (4\pi \times 8.85 \times 10^{-12})$ Correct to at least 3 significant figures. AFC. **Allow** 5.16×10^{-9} N AFC **Ignore** the sign of the answer.
1(b)(iii)	$a = (5.17 \times 10^{-9}) / (9.11 \times 10^{-31})$ $= 5.68 \times 10^{21}$ m s^{-2}	**A1**	Possible ECF from **1(b)(ii)**. Correct to at least 3 significant figures. AFC. **Allow** 5.67×10^{21} m s^{-2} or 5.66×10^{21} m s^{-2} as AFC answers
1(b)(iv)	$a = r\omega^2$ **and** $\omega = 2\pi / T$	**C1**	**Allow** $a = v^2 / r$ **and** $v = 2\pi r / T$
	$T = 2\pi \sqrt{[(2.11 \times 10^{-10}) / (5.68 \times 10^{21})]}$ $= 1.21 \times 10^{-15}$ s	**A1**	Possible ECF from **1(b)(iii)**. Correct to at least 3 significant figures. AFC. All permutation of unrounded values give the same 3 SF answer.

Question	Answer	Marks	Guidance
1(c)	radius: decreases	B1	
	acceleration: increases	B1	
	angular speed : increases	B1	

	decreases	same	increases
r	✓		
a			✓
ω			✓

Question	Answer	Marks	Guidance
2(a)(i)	(satellite) remains above the same point on the Earth's surface	B1	**Allow** 'equator' for 'surface' **Ignore** references to 'stationary'
2(a)(ii)	Any two points from: • equatorial • west to east • period = 24 hours	B2	List Rules apply. **Allow** orbit is in same direction as Earth's rotation **Allow** 'period is same as period of rotation of Earth' **Allow** '86 400 s' or '1 day' for '24 hours'.
2(b)(i)	$v = 2\pi R / T$	A1	**Allow** '*r*' for '*R*'
2(b)(ii)	$GMm / R^2 = mR\omega^2$	M1	
	clear use of $\omega = 2\pi / T$ **and** completion of algebra to reach $M = (4\pi^2R^3) / GT^2$	A1	
	or		
	$GMm / R^2 = mv^2 / R$	(M1)	
	clear use of $v = 2\pi R / T$ **and** completion of algebra to reach $M = (4\pi^2R^3) / GT^2$	(A1)	

Question	Answer	Marks	Guidance
2(c)	density = mass / volume	**C1**	<u>All three C1 marks are independent</u> **Allow** in symbols
	mass = $4\pi^2 \times [(6370 + 35\,900) \times 10^3]^3 / [(6.67 \times 10^{-11}) \times (24 \times 3600)^2]$	**C1**	$M = 5.988 \times 10^{24}$ kg (to 4 or more SF) implies C1.
	volume = $(4/3)\pi \times (6370 \times 10^3)^3$	**C1**	$V = 1.083 \times 10^{21}$ m^3 (to 4 or more SF) implies C1.
	average density = 5530 kg m^{-3}	**A1**	Must be to 3 significant figures. AFC. **Allow** AFC for 5560 kg m^{-3} (from T = 23h56m). An answer given to more than 3 significant figures which rounds to 5530 implies the three C1 marks.

Question	Answer	Marks	Guidance
3(a)	(objects are at) same temperature	**B1**	**Do not allow** 'constant' for 'same'
	(if in thermal contact) no net transfer of thermal energy (between them)	**B1**	**Allow** 'heat' for 'thermal energy'. **Allow** 'overall' or 'resultant' for 'net'. **Allow** 'exchange' or 'flow between them' for 'transfer'. **Do not allow** 'change' for 'transfer'.
3(b)(i)	thermistor absorbs thermal energy (to raise its temperature)	**B1**	**Allow** 'heat' for 'thermal energy'.
	thermal energy is transferred from the water, which cools	**B1**	
3(b)(ii)	$Q = mc\Delta\theta$	**C1**	
	$63 \times 4.2 \times (78.0 - 76.8) = 8.5 \times c \times (76.8 - 25.0)$	**C1**	
	specific heat capacity = $0.72\ \text{J g}^{-1}\ \text{K}^{-1}$	**A1**	Correct to at least 2 significant figures. AFC. (0.721)
3(c)	use a thermocouple	**B1**	**Allow** 'use a thermistor that is smaller / has lower mass'.
	smaller mass so will remove less thermal energy (from water)	**B1**	**Allow** 'energy' or 'heat' for 'thermal energy'. **Allow** 'heat capacity' for 'mass'
	or		
	warm the thermistor (to approximately 78 °C) before immersing it in the water	**(B1)**	For 2 / 2, both B1 marks must be from same method.
	smaller temperature change to reach equilibrium so will remove less thermal energy (from the water)	**(B1)**	

Question	Answer	Marks	Guidance
4(a)	change in internal energy = work done + transfer of thermal energy	C1	**Allow** any equation in which two quantities out of change in internal energy, work done and thermal energy transferred are added/subtracted to give the third. **Allow** 'heat' for 'thermal energy'. **Ignore** symbols unless defined. **Do not allow** change in work / thermal energy. Equality and summation must be clear (not just 'is' and 'and')
	increase in internal energy = work done on system + energy transferred to the system by heating	A1	**Allow** any set of clearly stated directions for the change in internal energy, work done and thermal energy transferred that is consistent with the version of the equation that is given. **Allow** 'system' and 'gas' interchangeably. **Ignore** definitions (correct or not) of internal energy. Equality and summation must be clear (not just 'is' and 'and')
4(b)(i)	$pV = NkT$	C1	**Allow** $pV = nRT$ and $N = nN_A$
	$V = (3.58 \times 10^{24} \times 1.38 \times 10^{-23} \times 298) / (1.84 \times 10^{5})$ $= 0.0800\ \text{m}^3$	A1	Full substitution and final answer to 3 significant figures needed. **Allow** '$8.31 / 6.02 \times 10^{23}$' for '$1.38 \times 10^{-23}$'. Unit not needed but any unit given must be correct.
4(b)(ii)	$n = (3.58 \times 10^{24}) / (6.02 \times 10^{23})$ $= 5.95\ \text{mol}$	A1	Correct to at least 3 significant figures. AFC. (5.947) **Allow** AFC for 5.94 mol (from use of value of V in **4(b)(i)** with $pV = nRT$). No ECF from **4(b)(i)**.
4(b)(iii)	$E_K = (3 / 2)kT$	C1	
	$= (3 / 2) \times 1.38 \times 10^{-23} \times 298$ $= 6.17 \times 10^{-21}\ \text{J}$	A1	Correct to at least 3 significant figures. AFC. (6.169)

Question	Answer	Marks	Guidance
4(b)(iv)	no intermolecular forces	**B1**	**Allow** 'negligible' for 'no'.
4(b)(v)	$U = 3.58 \times 10^{24} \times 6.17 \times 10^{-21}$ $= 2.21 \times 10^{4}$ J	**A1**	Possible ECF from **4(b)(iii)**. Correct to at least 3 significant figures. AFC. (2.208) **Allow** 22.1 kJ.
4(c)(i)	no change in volume so no work done (on/by gas)	**B1**	**Allow** in symbols e.g. $\Delta V = 0$ so $W = 0$
	Q = [(584 – 184) / 184] U_A = (+)50 U_A / 23 **or** (+)2.2 U_A	**A1**	Correct to at least 2 significant figures. (2.17). **Allow** 'U' for 'U_A'. **Allow** any simple ratio that computes to 2.2 rounded to 2 significant figures.
4(c)(ii)	(no thermal energy transfer so) increase in internal energy = work done on gas **or** internal energy at C is double the internal energy at A	**B1**	**Allow** '(no thermal energy transfer so) decrease in internal energy = work done by gas'. **Allow** $U_C = 2U_A$
	$W = U_A – (50\ U_A / 23)$ = – 27 U_A / 23 **or** –1.2 U_A	**A1**	Possible ECF from **4(c)(i)** if Q in terms of U_A only Correct to at least 1 decimal place. (–1.17). **Allow** 'U' for 'U_A'. **Allow** any simple ratio that computes to –1.2 rounded to 2 significant figures.

Question	Answer	Marks	Guidance
5(a)(i)	complete loop enclosing the origin	**B1**	There must be an attempt to draw curves and not just straight lines joining the intercepts
	loop cutting x-axis at $x = \pm 2.5$ cm and never at larger magnitudes of x	**B1**	**Allow** tolerance ±½ small square horizontally.
	loop cutting v-axis at $v = \pm 4.4$ cm s^{-1} and never at larger magnitudes of v	**B1**	**Allow** tolerance ±½ small square vertically from 4.5. (2 small squares from 5.0 = 4.5) Special Case: **Allow** 2 / 3 for half-loop that passes through three of the four axis intercepts within tolerance. Annotate cross, tick, tick horizontally.
5(a)(ii)	$v_0 = \omega x_0$ **and** $\omega = 2\pi f$	**C1**	Use of r, R or A for x_0 not sufficient unless defined or clarified by the substitution.
	frequency = $4.4 / (2.5 \times 2\pi) = 0.28$ Hz	**A1**	Full substitution and answer needed. Unit not needed but any unit given must be correct.
5(b)(i)	(oscillation of object at) maximum amplitude	**B1**	**Allow** 'vibration' for 'oscillation'.
	when driving frequency = natural frequency (of system)	**B1**	**Allow** 'platform' or 'motor' or 'forced' or 'external' for 'driving'. **Allow** 'ball' for 'system'. **Allow** 'matches' for '=' **Allow** 'nature' for 'natural' annotate with BOD
5(b)(ii)	line from $f = 0$ with amplitude never zero when $f > 0$, rising continuously to a single peak and then falling continuously until $f = 0.40$ Hz	**B1**	**Allow** zero amplitude everywhere except at a single spike (but not zero amplitude anywhere if peak is not shown as a single spike).
	(single) peak shown at $f = 0.28$ Hz	**B1**	**Allow** tolerance ±1 small square horizontally. No ECF from **5(a)(ii)**.

Question	Answer	Marks	Guidance
6(a)(i)	time constant = RC	C1	
	resistance = $2.4 / (47 \times 10^{-6})$ $= 5.1 \times 10^{4}\ \Omega$ $= 51\ \text{k}\Omega$	A1	Correct to at least 2 significant figures. AFC. (51.1)
6(a)(ii)	discharge time for each cycle = 2.5 s	C1	
	$V_{MIN} = 1.50 \exp(-2.5 / 2.4) = 0.53$ V	A1	Full substitution and answer needed. (0.529) Unit not needed but any unit given must be correct.
6(b)	straight horizontal lines at $V_C = 1.50$ V from $t = 0$ to 2.5 s and $t = 5.0$ to 7.5 s	B1	**Allow** tolerance ±½ small square vertically.
	smooth discharge curve of continuously decreasing negative gradient from $t = 2.5$ s to 5.0 s and $t = 7.5$ s to 10.0 s	B1	**Do not allow** if line becomes horizontal. Special Case: **Allow** one of the first two B1 marks if the phase is inverted but all otherwise correct.
	discharge curves show minimum voltage at $V_C = 0.53$ V	B1	**Allow** tolerance ±½ small square vertically. **Allow** any shape containing at least two minima with all minima shown at 0.53 V within tolerance and never below 0.53 V.
6(c)	smaller time spent discharging (before re-charging)	B1	
	minimum p.d. is greater (than 0.53 V)	B1	

Question	Answer	Marks	Guidance
7(a)	current for which the direction regularly reverses	**B1**	**Allow** 'direction changes' for 'direction reverses' **Allow** 'periodically', 'repeatedly' or 'continuously' for 'regularly'
7(b)(i)	straight parallel horizontal lines shown inside the solenoid	**B1**	Minimum 5 lines needed inside. **Allow** curvature to start just before the ends.
	correct bar magnet field pattern shown outside the solenoid	**B1**	Minimum 5 lines needed outside. **Do not allow** lines merging or crossing At least one complete loop above and one below the central axis and one horizonal line outside each pole required. To award both of the B1 marks, the lines inside and outside must be continuous with each other.
	arrows showing direction inside the solenoid is right to left	**B1**	Arrows can be anywhere on field lines (whether inside or outside the solenoid) but must be consistent with correct direction (extrapolated if necessary) inside. Minimum of 1 arrow inside and 1 arrow outside needed, but all arrows shown must be in correct direction.
7(b)(ii)	N shown at left-hand end of solenoid and S shown at right-hand end	**B1**	No ECF from **7(b)(i)**. **Allow** omission of either N or S if the other letter is present in the correct place.
7(c)(i)	$200\pi = 2\pi / T$ so $T = 0.010$ s	**A1**	Full substitution and answer needed; π must be shown on both sides of the equation. **Allow** 0.01 s

Question	Answer	Marks	Guidance
7(c)(ii)	two cycles of a sinusoidal curve drawn, with period 0.010 s and amplitude 2.0 mT	**B1**	**Allow** tolerance ±½ small square. Judge period on the crossing points of the *t*-axis. 'Sinusoidal' judged by curvature at peaks and troughs which are not at edges of the grid.
	correct phase, with $B = 0$ at (and only at) $t = 0.0025$ s, $t = 0.0075$ s, $t = 0.0125$ s and $t = 0.0175$ s.	**B1**	**Ignore** amplitude and times of peaks / troughs. Assess phase only by the crossing points of *t*-axis.
7(d)(i)	$\Phi = NBA$	**C1**	**Allow** $\Phi = BA$ without N for the first C1 mark
	$= 45 \times 2.0 \times 10^{-3} \times \pi \times (2.8 \times 10^{-3})^2$	**C1**	**Ignore** POT in maximum flux density in second C1 mark
	$= 2.2 \times 10^{-6}$ Wb	**A1**	Correct to at least 2 significant figures. AFC. (2.22) Unit needed with answer for the A1 mark. **Allow** 'T m^2' or 'V s' or 'kg m^2 s^{-1}' for 'Wb'. **Allow** WB for Wb The POT in the answer must be consistent with the unit given, e.g. 2.2×10^{-3} mWb
7(d)(ii)	draw tangent to determine gradient at steepest part of curve	**B1**	
	steepest gradient × area (of search coil) × number (of turns) gives maximum rate of cutting flux	**B1**	**Accept** '*A*' for 'area' and '*N*' for 'number'
	maximum e.m.f. = maximum rate of cutting flux (by Faraday's law)	**B1**	**Accept** symbol for maximum e.m.f. <u>Alternative method for the 2nd and 3rd B1 marks:</u> e.m.f = rate of cutting flux (B1) (**Do not allow** in symbols because Φ defined in question as maximum flux) maximum e.m.f = steepest gradient × area × number (B1) (**Accept** symbol for maximum e.m.f., '*A*' for 'area' and '*N*' for 'number') Both marks must be from the same method.

Question	Answer	Marks	Guidance
8(a)(i)	photoelectric effect	**B1**	**Allow** 'photoelectric emission' or 'photoemission'
8(a)(ii)	minimum frequency needed to cause emission (of electrons)	**B1**	
8(a)(iii)	Any three points from: • electrons need a minimum energy to leave the surface • photon absorbed by electron must have enough energy for electron to leave • photons are packets of energy proportional to frequency • minimum photon energy means minimum frequency (of radiation)	**B3**	**Allow** 'photon absorbed by electron must have energy at least equal to the work function (energy)' or reverse argument **Allow** 'quantum' for 'packet'
8(b)(i)	$hc / \lambda = \Phi + E_K$	**C1**	**Allow** $hf = \Phi + E_K$ **and** $f = c / \lambda$ **Allow** $hc / \lambda = hc / \lambda_0 + E_K$
	$h \times 3.00 \times 10^8 \times [(1 / 178 \times 10^{-9}) – (1 / 254 \times 10^{-9})]$ $= (5.27 – 1.91) \times 10^{-19}$	**C1**	
	$h = 6.66 \times 10^{-34}$ J s	**A1**	Must be given to 3 significant figures. AFC. No credit is implied by 6.63×10^{-34} J s.

Question	Answer	Marks	Guidance
8(b)(ii)	Φ = [(6.66 × 10^{-34} × 3.00 × 10^{8}) / (178 × 10^{-9})] – (5.27 × 10^{-19}) **or** Φ = [(6.66 × 10^{-34} × 3.00 × 10^{8}) / (254 × 10^{-9})] – (1.91 × 10^{-19}) (= 5.95 × 10^{-19} J)	**C1**	Independent C1 marks. **Allow** '6.63' for '6.66'. **Allow** '6.63' for '6.66'. Possible ECF from **8(b)(i)**. 5.9 or 6.0 × 10^{-19} J implies C1.
	division by 1.60 × 10^{-19}	**C1**	
	Φ = (5.95 × 10^{-19}) / (1.60 × 10^{-19}) = 3.7 eV	**A1**	Correct to 2 significant figures. AFC. **Allow** answers to greater than 2 SF for this question if answer is correct when rounded to 2 SF. Both sets of data and both values of *h* give 3.7.

Question	Answer	Marks	Guidance
9(a)	p.d. applied to crystal causes it to distort	**B1**	**Allow** 'vibrate', 'compress', 'contract', 'extend', 'cause strain' for 'distort' **Allow** 'voltage' for 'p.d.' for the first B1 mark
	alternating p.d. is applied (causing crystal to vibrate)	**B1**	'Alternating p.d. applied to crystal causes it to vibrate' gets both MP1 and MP2.
	vibrations of crystal at ultrasound frequency cause oscillations in the air	**B1**	**Allow** any named external medium for 'air'.
9(b)(i)	*Z* = density × speed (of sound)	**C1**	**Allow** in symbols
	Z = 8960 × 4720 = 4.23 × 10^{7} kg m^{-2} s^{-1}	**A1**	Correct to at least 3 significant figures. AFC. (4.229) Unit needed with answer for the A1 mark.

Question	Answer	Marks	Guidance
9(b)(ii)	Any three points from: Up to two points from: • thickness of X = 12.0 cm (total) / 10.0 cm (along PQ) • thickness of Y = 2.0 cm • thickness of X is greater than thickness of Y Up to two points from: • (linear) attenuation coefficient of X = 3.2 cm^{-1} • (linear) attenuation coefficient of Y = 1.5 cm^{-1} • (linear) attenuation coefficient greater for X than for Y Up to one point from: • intensity transmission coefficient at X–Y boundary = 0.37 • intensity reflection coefficient at X–Y boundary = 0.63	**B3**	List Rules apply. All numerical values must be given with a unit and be correct to at least 2 significant figures. **Ignore** points which do not relate to the structure or the materials from which it is made **Ignore** points that are simply descriptions of or direct read-offs from the graphs. **Ignore** working space. No ECF. **Allow** thickness of whole structure = 12 cm **Allow** 2 sections of X of thickness 5 cm **Allow** 12 cm / 10 cm **Allow** 2 cm, but if given to 2 significant figures must be 2.0 **Allow** 'absorption' for 'attenuation' **Allow** range 0.30 to 0.45. **Allow** range 0.55 to 0.70.

Question	Answer	Marks	Guidance
10(a)(i)	(astronomical) object of known luminosity	**B1**	**Allow** 'star' for 'astronomical object'.
10(a)(ii)	measure radiant flux intensity	**B1**	The quantity must be correctly named for this mark.
	calculate distance using $F = L / 4\pi d^2$	**B1**	**Allow** 'determine' for 'calculate'
10(b)(i)	star is moving away from observer	**B1**	**Allow** 'galaxy' for 'star'. **Allow** 'Earth' or 'us' for 'observer'.
	observed wavelength is therefore greater (than the emitted wavelength)	**B1**	**Do not allow** 'increasing' etc. implying continuing change
10(b)(ii)	$T_{STAR} = \lambda_0 T_0 / \lambda_{STAR}$	**A1**	
10(b)(iii)	$L = 4\pi\sigma R^2 T^4$ radius = $\sqrt{[L / 4\pi\sigma T_{STAR}^4]}$ where σ is the Stefan–Boltzmann constant	**A1**	Must be in terms of T_{STAR}. **Allow** 'Stefan' for 'Stefan–Boltzmann'.