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CAMBRIDGE
International Education

Cambridge International AS & A Level

PHYSICS **9702/41**

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.

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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.

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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.

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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.

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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

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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

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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 <u>independent</u> 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 <u>mandatory</u> 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 <u>compensatory</u> 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 <u>answer</u> marks. They may depend on an **M** mark or allow a **C** mark to be awarded by implication.

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Question	Answer	Marks	Guidance
1(a)	work done per unit mass	**B1**	Ratio must be clear. **Allow** 'energy' for 'work done'. **Ignore** symbols unless they are defined. **Ignore** references to units. **Not** any other type of named energy.
	work done (on mass) moving mass from infinity (to the point)	**B1**	**Allow** work done by mass moving to infinity.
1(b)(i)	potential is (defined as) zero at infinity	**B1**	**Allow** 'it' / ϕ / GPE = 0 at infinity
	work is done on (two) masses to move them apart from each other **or** work is done by (two) masses as they move towards each other	**B1**	**Allow** 'mass and planet' for 'two masses'. **Allow** 'increasing the separation of' for 'move them apart'. **Allow** 'decreasing the separation of' for 'they move towards each other' **Allow** 'potential energy of (two) masses decrease as they move toward each other' **Allow** 'potential energy of (two) masses increase as they move away from each other'
1(b)(ii)	$M = \Phi R / G$	**M1**	**Allow** with a minus sign. **Allow** ϕ for Φ.
	G is the (universal) gravitational constant	**A1**	**Ignore** references to numerical value. **Ignore** 'gravity constant'
1(b)(iii)	$g_0 = \Phi / R$	**A1**	**Allow** with a minus sign. **Allow** ϕ for Φ. No ECF of wrong expression in **1(b)(ii)**

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Question	Answer	Marks	Guidance
1(b)(iv)	curve in at least one quadrant passing through (±R, ±g_0) and (±2R, ±$\frac{1}{4}g_0$) and a non-zero value of g at ±3R	**B1**	**Ignore** anything drawn in the –R to R region. **Allow** ±½ small square tolerance vertically.
	curve between –3R and –R of increasing magnitude of gradient and magnitude of g **and** curve between R and 3R of decreasing magnitude of gradient and magnitude of g	**B1**	Curves must get to within 2 small squares horizontally of –3R and 3R, and, if horizontal, horizontal for no more than 4 small squares. If in doubt, use ruler to test curvature between ±R and ±3R, ±R and ±2R, and ±2R and ±3R. Drawn line must be entirely on the correct side of the ruler, and not touching it apart from at the end points.
	two lines drawn, one in the top left quadrant, the other in the bottom right quadrant	**B1**	**Do not allow** if lines are drawn in either of the other two quadrants.

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Question	Answer	Marks	Guidance
2(a)	gas which obeys $pV \propto T$ (under all conditions)	**M1**	**Allow** $pV = nRT$ or $pV = NkT$ for $pV \propto T$.
	where T is the thermodynamic temperature	**A1**	**Allow** 'absolute' or 'Kelvin' for 'thermodynamic'.
2(b)(i)	measures absolute temperature (unlike liquid in glass) **or** much greater range of temperature (than liquid in glass) **or** gives a measurement that does not depend on the properties of a (real) substance	**B1**	**Allow** reverse argument. **Allow** 'thermodynamic temperature' Ignore 'Kelvin' **Allow** 'liquid in glass only accurate at fixed points'. **Allow** 'measures higher / lower temperatures'.
2(b)(ii)	very small mass of substance **or** rapidly changing temperatures	**B1**	**Allow** 'amount' or 'volume' for 'mass'. **Allow** remote reading using a thermocouple. **Ignore** 'small changes in temperature'
2(c)	$357^2 + 424^2 + 509^2 + 286^2 + 435^2$ (= 837 327)	**C1**	Value 167 465 or 915 implies C1.
	$c_0 = \sqrt{\left(\frac{837\,327}{5}\right)}$ $= 409\ \text{m s}^{-1}$	**A1**	Must be given to 3 significant figures. AFC. Answer given to more than 3SF, that rounds to 409, implies the C1 mark.
2(d)(i)	$N = n \times N_A$	**C1**	
	$n = (5.0 \times 10^{23}) / (6.02 \times 10^{23})$ $= 0.83$ mol	**A1**	Correct to at least 2 significant figures. AFC. (0.831)

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Question	Answer	Marks	Guidance
2(d)(ii)	$\frac{1}{2}m\langle c^2\rangle = (3/2)\,kT$	C1	**Allow** $pV = NkT$ <u>and</u> $p = \left(\frac{1}{3}\right)\left(\frac{Nm}{V}\right)\langle c^2\rangle$. **Allow** $pV = nRT$ <u>and</u> $p = \left(\frac{1}{3}\right)\left(\frac{Nm}{V}\right)\langle c^2\rangle$ **Allow** $\langle c^2\rangle = \left(\frac{3kT}{m}\right)$ **Allow** c_{rms} for $\sqrt{\langle c^2\rangle}$ **Ignore** $\langle c\rangle^2$
	$T_0 = [(3.34 \times 10^{-27}) \times 409^2] / (3 \times 1.38 \times 10^{-23})$ $= 13.5\,\text{K}$	A1	Possible ECF from **2(c)** or **2(d)(i)**. Correct to at least 3 significant figures. AFC. (13.51)
2(d)(iii)	line <u>starting</u> at (T_0, c_0) with positive gradient at that point	B1	
	line with decreasing positive gradient	B1	**Allow** line becoming horizontal at the end but not negative gradient.
	line that passes through (0, 0) when extrapolated back from $T = T_0$	B1	Ignore any line drawn by candidate before T_0. Extrapolate candidate's line from T_0 and beyond back to $T = 0$. Award MP3 if there is a conceivable reasonable extension of their line that passes through the test box centred on the origin, without having to resort to incorrect curvature.

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Question	Answer	Marks	Guidance
3(a)	sum of potential energy and kinetic energy	**B1**	**Allow** 'PE' or 'E_P' for 'potential energy'. **Allow** 'KE' or 'E_K' for 'kinetic energy'.
	(total) energy of random motion of particles	**B1**	**Allow** 'distribution' for 'motion'. **Allow** 'random energy of particles'. **Allow** 'atoms' or 'molecules' for 'particles'. **Do not allow** 'system' or 'gas' for 'particles'. **Do not allow** 'a particle' for 'particles'. **Ignore** any reference to first law of thermodynamics.
3(b)(i)	$pV = NkT$	**C1**	**Allow** $pV = nRT$ **and** $N = nN_A$.
	$V = (8.7 \times 10^{23} \times 1.38 \times 10^{-23} \times 300) / (2.0 \times 10^5) = 0.018\ m^3$	**A1**	Full substitution and answer needed. Unit not needed but any unit given must be correct. **Allow** '$8.31 / 6.02 \times 10^{23}$' for '$1.38 \times 10^{-23}$'.
3(b)(ii)	potential energy of <u>molecules</u> is zero	**B1**	**Allow** 'E_P' or 'PE' for 'potential energy' **Allow** 'PE = 0 because there are no intermolecular forces'
	internal energy $= \left(\frac{3}{2}\right) \times NkT$	**C1**	**Allow** internal energy = $\left(\frac{3}{2}\right) pV$.
	$= \left(\frac{3}{2}\right) \times 8.7 \times 10^{23} \times 1.38 \times 10^{-23} \times 300$ $= 5400\ J$	**A1**	Correct to at least 2 significant figures. (5403). **Allow** 5.4 kJ if unit is clear.

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Question	Answer	Marks	Guidance
3(c)	Any three points from: Up to two points relating to change AB • no change in internal energy • work done = thermal energy transferred • work done on the gas **and** thermal energy transferred from it Up to two points relating to change BC • internal energy is halved • no work done (on/by gas) • decrease in internal energy = thermal energy removed Up to two points relating to change CA • internal energy is doubled • work done by gas = 1.8 kJ • thermal energy transferred to gas = 4.5 kJ Up to two points relating to the complete cycle ABCA • no overall change in internal energy • overall work is done on gas **and** thermal energy is removed from it • net work done = net thermal energy transferred	**B3**	List Rules apply. All numerical values must be given with a unit and be correct to at least 2 significant figures. **Ignore** points that are simply descriptions of or direct read-offs from the graph. **Ignore** working space. No ECF. Throughout: Must be clear which aspect of the cycle each point is being made in relation to. **Ignore** points that are not related to internal energy, thermal energy or work done **Ignore** symbols unless defined **Allow** 'heat' for 'thermal energy'. **Allow** 'internal energy decreases' unless quantified as a factor different than halving. **Allow** internal energy becomes 2.7 kJ. **Allow** thermal energy removed = 2.7 kJ. **Allow** 'internal energy increases' unless quantified as a factor different than two. **Allow** 'internal energy becomes 5.4 kJ / increases by 2.7 kJ'

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Question	Answer	Marks	Guidance
4(a)(i)	magnitudes (of electric fields) are equal	**B1**	**Allow** 'strength' for 'magnitude'
	Any two from: • (electric field) due to proton is to the right • (electric field) due to electron is to the right • directions (of electric fields) are the same	**B2**	**Allow** towards electron / away from proton **Allow** towards electron / away from proton. **Do not allow** if both directions given to the left. If all three points are attempted, and two are correct and one is incorrect, treat as one contradiction and award 1/2 (CON).
4(a)(ii)	magnitudes (of electric potentials) are equal	**B1**	
	Any two from: • (electric potential) due to proton is positive • (electric potential) due to electron is negative • signs (of electric potentials) are opposite	**B2**	**Do not allow** if the signs are the wrong way around. **Do not allow** 'in opposite directions' If all three points are attempted, and two are correct and one is incorrect, treat as one contradiction and award 1/2 (CON). If BP3 is incorrect purely due to use of 'in opposite directions', this does not negate BP1 and BP2.
4(b)(i)	$F = Q_1Q_2 / 4\pi\varepsilon_0R^2$	**C1**	C1 mark is for any correct general statement of Coulomb's law, using standard symbols. **Allow** Q, q and e for Q_1 and Q_2. **Allow** x or r for R.
	$F = e^2 / 16\pi\varepsilon_0x^2$	**A1**	Treat correct answer as AFC. **Ignore** sign
4(b)(ii)	$E_P = 2Fx$	**A1**	**Ignore** sign

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Question	Answer	Marks	Guidance
5(a)	charge / potential (difference)	**M1**	Ratio must be clear. **Allow** 'p.d.' or 'voltage' for 'potential difference'. **Ignore** any symbols unless they are defined. **Ignore** any reference to units.
	charge is charge on one plate **and** potential is p.d. between the plates	**A1**	**Allow** 'across both plates' or 'across parallel plates' for 'between the plates'. For the A1 mark, must be in terms of p.d. or potential difference, not just voltage.
5(b)	$E = V_X = V_Y$	**B1**	Must be an explicit statement. Allow in words provided all three terms in the expression are clear. **Allow** V or V_T for E Allow in terms of V_1 and V_2
	$Q_T = Q_X + Q_Y$	**M1**	Must be an explicit statement. Allow in words provided all three terms in the expression are clear. **Allow** Q for Q_T Allow in terms of Q_1 and Q_2
	$C_T V = C_X V + C_Y V$ leading to $C_T = C_X + C_Y$ **or** $Q_T / V = Q_X / V + Q_Y / V$ leading to $C_T = C_X + C_Y$	**A1**	**Allow** any one of E, V_T, V_X, V_Y for V provided same symbol is used for all three terms. **Allow** the first part left in terms of E, V_X and V_Y if the explicit B1 mark statement is clear. Everything required for the A1 mark must be in terms of C_T, C_X and C_Y,

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Question	Answer	Marks	Guidance
5(c)	$E = \frac{1}{2}CV^2$	**C1**	Independent C1 marks – neither implies the other, and XP in one does not negate the other. **Allow** $E = \frac{1}{2}QV$ **and** $Q = CV$
	$C_T = (1/C + 1/2C)^{-1}$ **or** $1/C_T = 1/C + 1/2C$ $(C_T = \frac{2}{3}C)$	**C1**	C1 is for the working leading to $\frac{2}{3}C$. $\frac{2}{3}C$ does not need to be seen, but its appearance implies C1.
	$1.30 \times 10^{-3} = \frac{1}{2} \times \frac{2}{3}C \times 6.00^2$ $C = 1.08 \times 10^{-4}$ F $= 108\ \mu$F	**A1**	This line of working implies both C1 marks. Correct value of C in F implies both C1 marks. Correct to at least 3 significant figures. (AFC). Must be in μF for the A1 mark.

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Question	Answer	Marks	Guidance
6(a)	• force per unit length • force per unit current • length / current perpendicular to field *1 mark for any two bullet points, 2 marks for all three bullet points.*	**B2**	Ratio must be clear. **Ignore** symbols unless defined. **Ignore** references to units. 'Force per unit (current × length)' achieves both BP1 and BP2. **Allow** 'wire perpendicular to field'. **Allow** 'flux (density)' for 'field'. **Do not allow** 'force' for 'field'.
6(b)(i)	(at X, magnetic) force on <u>particles</u> is to the left	**B1**	
	left hand rule tells us the (effective) current is in the <u>direction</u> of movement (of the particles), <u>so</u> charge is positive	**B1**	**Allow** 'beam' or 'velocity' for 'movement' **Allow** 'down' for 'direction of movement'
6(b)(ii)	(magnetic) force is always perpendicular to the <u>direction</u> of motion (of the particles)	**B1**	**Allow** 'beam' or 'velocity' for 'direction of motion'. **Allow** 'centripetal' for 'magnetic'
	(magnetic) force changes direction only, and not the speed of the particles **or** (magnetic) force causes centripetal acceleration	**B1**	**Allow** 'centripetal' for 'magnetic'
6(c)(i)	$a = v^2 / r$	**C1**	**Allow** $F = ma$ **and** $F = mv^2 / r$
	$= (7.3 \times 10^4)^2 / (0.5 \times 8.2 \times 10^{-2}) = 1.3 \times 10^{11}$ m s^{-2}	**A1**	Full substitution and answer needed. Allow 0.041 for $0.5 \times 8.2 \times 10^{-2}$ Unit not needed, but if a unit is given it must be correct.

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Question	Answer	Marks	Guidance
6(c)(ii)	$BQv = ma$	**C1**	**Allow** $Bq = mv / r$. No ECF from **6(c)(i)**.
	$B = (2.0 \times 10^{-26} \times 1.3 \times 10^{11}) / (3.2 \times 10^{-19} \times 7.3 \times 10^{4})$ $= 0.11$ T	**A1**	Correct to at least 2 significant figures. AFC. (0.111) Unit needed with answer for A1 mark. **Allow** kg A^{-1} s^{-2} for T **Allow** kg C^{-1} s^{-1} for T **Allow** N A^{-1} m^{-1} for T **Allow** Wb m^{-2} for T **Allow** V s m^{-2} for T
6(d)	beam shown entering the field at X along same line, and deflecting in same direction in field	**B1**	
	circular path with half the radius along the whole length of the curve	**B1**	Judge half the radius approximately by eye

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Question	Answer	Marks	Guidance
7(a)(i)	allows the current (unhindered) in one direction	**B1**	**Allow** 'converts a.c. into d.c.'
	blocks the current (completely) in the other direction	**B1**	
7(a)(ii)	diode shown connecting the wires in one gap, and direct connection across the other gap	**B1**	**Allow** two diodes if in consistent directions **Allow** a single diode in parallel with resistor **Ignore** a capacitor in parallel with resistor Do not allow if there any other components added into the circuit that would stop the circuit from working as a rectification circuit.
	correct symbol used for diode	**B1**	**Ignore** presence / absence of circle and / or line through the triangle. If more than one diode in circuit, all must have the correct symbol
7(b)	V_1 unrectified: r.m.s. voltage shown as $V_0 / \sqrt{2}$	**B1**	
	V_2 unrectified: r.m.s. voltage shown as V_0	**B1**	
	V_1 rectified: r.m.s. voltage shown as $V_0 / 2$	**B1**	
	V_2 rectified: r.m.s. voltage shown as $V_0 / \sqrt{2}$	**B1**	

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Question	Answer	Marks	Guidance
8(a)	packet / quantum of <u>energy</u>	**M1**	**Allow** 'discrete <u>amount</u> of energy'. (Not just 'value' for 'amount'). **Allow** 'quanta' or 'bundle' for 'packet'.
	of electromagnetic radiation	**A1**	**Allow** 'em' for 'electromagnetic'. **Allow** 'wave' or 'emission' for 'radiation'. **Ignore** any specific named part of the spectrum (such as 'light'). **Do not allow** the second mark if the idea is conveyed that the em radiation is 'carrying' the photons. (It needs to be clear that the photons <u>are</u> the em radiation). E.g. not 'in' or 'from' for 'of'. 'Quantum / packet of electromagnetic energy' is awarded full credit.
8(b)(i)	electrons	**B1**	
8(b)(ii)	electrons are decelerated by target	**B1**	**Allow** 'charged particles' for 'electrons' throughout (but **not** an incorrectly named particle). **Allow** 'anode' for 'target' **Allow** 'metal' for 'target'
	(some) kinetic energy of electrons becomes energy of photons	**B1**	**Allow** 'X-ray' for 'energy of'

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Question	Answer	Marks	Guidance
8(b)(iii)	some electron kinetic energy dissipated as thermal energy (in target)	**B1**	**Do not allow** 'electrons have a range of kinetic energies' **Allow** 'heat' for 'thermal energy'. **Allow** omission of 'electron' or 'kinetic' but not both. **Allow** 'electron KE' for 'electron kinetic energy'.
	wavelength (of X-rays) is inversely proportional to photon energy	**B1**	**Ignore** $E = hc / \lambda$ unless E defined as photon energy, λ defined as wavelength, and hc stated as constant
	maximum photon energy (and therefore minimum wavelength) when all of the electron kinetic energy becomes the energy of a photon	**B1**	**Allow** omission of 'electron' or 'kinetic' but not both. **Allow** 'electron KE' for 'electron kinetic energy'.
8(b)(iv)	$hc / \lambda = qV$	**C1**	**Allow** $hf = qV$ **and** $f = c / \lambda$ **Allow** e for q. No credit for $hv / \lambda = qV$ unless v is clarified as speed of light in substitution.
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (1.60 \times 10^{-19} \times 52.0 \times 10^{3})$	**C1**	
	$= 2.39 \times 10^{-11}$ m	**A1**	Correct to at least 3 significant figures. AFC. (2.391)
8(c)	discussion of differences in (linear) attenuation coefficient	**B1**	**Allow** 'absorption coefficient' for 'attenuation coefficient'
	good contrast when the transmitted intensities (through the two materials) are very different	**B1**	**Allow** 'not good contrast when the transmitted intensities (through the two materials) are similar'. **Allow** 'pass through' for 'transmitted'

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Question	Answer	Marks	Guidance
9(a)	difference between mass of nucleus and mass of constituent nucleons	**M1**	**Allow** 'protons and neutrons' for 'nucleons'. Mass must be mentioned once.
	when separated to infinity	**A1**	**Ignore** 'mass equivalence of binding energy'.
9(b)(i)	alpha decay identified as producing Ra-224 (plus He-4)	**B1**	
	β^+ decay identified as producing Ac-228 **and** β^- decay as producing Pa-228	**B1**	Must be the correct way around.
	alpha decay products calculated to have total mass defect of 1.877217u	**B1**	Any appearance of the value 1.877217u is sufficient to award the mark.
	reaction only happens if mass defect of products is greater than mass defect of parent nucleus (so decay is alpha and is not beta)	**B1**	
9(b)(ii)	$E = (\Delta)mc^2$	**C1**	
	$= (1.877217 - 1.871290) \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	**C1**	1.877217 may be left as 1.846840 + 0.030377. 1.877217 – 1.871290 may be substituted as 0.005927 **Allow** subtraction either way round Treat use of 1.67×10^{-27} as a TE in this C1 mark (gives an answer of 5.57 MeV).
	$(= 8.85 \times 10^{-13}$ J) $= 5.53$ MeV	**A1**	Correct 3 SF answer in J implies both C1 marks. Must be given to 3 significant figures. Answer must be positive for A1.

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Question	Answer	Marks	Guidance
10(a)	temperature inversely proportional to wavelength	**M1**	**Allow** 'product of wavelength and temperature is a constant' **Ignore** symbols unless defined. **Ignore** references to units. **Allow** 'absolute' or 'in Kelvin' for 'thermodynamic'.
	temperature is thermodynamic temperature of surface, and wavelength is the wavelength at which maximum emission rate occurs	**A1**	**Not** 'maximum wavelength'. **Allow** 'intensity' for 'emission rate'
10(b)(i)	$L = 4\pi \times 5.67 \times 10^{-8} \times (6.96 \times 10^{8})^2 \times 5770^4$	**C1**	
	$= 3.83 \times 10^{26}$ W	**A1**	Correct to at least 3 significant figures. AFC. (3.826)
10(b)(ii)	$F = L / 4\pi d^2$	**C1**	
	$= 3.83 \times 10^{26} / (4\pi \times (1.52 \times 10^{11})^2)$	**C1**	Possible ECF from **10(b)(i)**.
	$= 1320$ W m^{-2}	**A1**	Correct to at least 3 significant figures. AFC. (1317) Unit needed with answer for A1 mark. **Allow** J s^{-1} m^{-2} for W m^{-2}
10(b)(iii)	temperature = 5770 / 0.581 = 9930 K	**A1**	Correct to at least 3 significant figures. AFC.

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