

Cambridge International AS & A Level

PHYSICS**9702/41**

Paper 4 A Level Structured Questions

May/June 2025

MARK SCHEME

Maximum Mark: 100

Published

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This document consists of **19** printed pages.

PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptions for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors 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
	arithmetic error
	benefit of the doubt given
	contradiction in response, mark not awarded
	correct point or mark awarded
	error carried forward applied
	error in number of significant figures
	incorrect or insufficient point ignored while marking the rest of the response
	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

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.
<u> </u>	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.

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.

Question	Answer	Marks
1(a)	work done per unit mass	B1
	work (done in) moving mass from infinity (to the point)	B1
1(b)(i)	evidence of addition of 3.4×10^6 to 1.7×10^6 or 6.8×10^6	C1
	$GM \times 122 / (5.1 \times 10^6)$ or $GM \times 122 / (10.2 \times 10^6)$	C1
	$6.67 \times 10^{-11} \times M \times 122 \times [(5.1 \times 10^6)^{-1} - (10.2 \times 10^6)^{-1}] = 5.1 \times 10^8$	A1
	leading to $M = 6.4 \times 10^{23}$ kg	
1(b)(ii)	$\phi = (-) (6.67 \times 10^{-11} \times 6.4 \times 10^{23}) / (3.4 \times 10^6)$	C1
	$= -1.3 \times 10^7 \text{ J kg}^{-1}$	A1
1(c)(i)	Mars takes (just under) 25 hours to rotate once on its axis	B1
1(c)(ii)	orbit is equatorial or orbit is in same direction as direction of rotation of Mars	B1

Question	Answer	Marks
2(a)	(electric) force is (directly) proportional to product of charges	B1
	force (between point charges) is inversely proportional to the square of their separation	B1
2(b)(i)	charge = $(+)2e$	A1
2(b)(ii)	$F = 2 \times (1.60 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (170 \times 10^{-12})^2] = 1.6 \times 10^{-8} \text{ N}$	A1
2(c)(i)	$F = mv^2 / r$	C1
	$v = [(1.6 \times 10^{-8} \times 170 \times 10^{-12}) / (9.11 \times 10^{-31})]^{1/2}$ $= 1.7 \times 10^6 \text{ m s}^{-1}$	A1
2(c)(ii)	$F = mr\omega^2$ and $\omega = 2\pi / T$ $F = 4\pi^2 mr / T^2$	C1
	$T = [(4\pi^2 \times 9.11 \times 10^{-31} \times 170 \times 10^{-12}) / (1.6 \times 10^{-8})]^{1/2}$ $= 6.2 \times 10^{-16} \text{ s}$	A1
	or	
	$v = 2\pi r / T$	(C1)
	$T = (2\pi \times 170 \times 10^{-12}) / (1.73 \times 10^6)$ $= 6.2 \times 10^{-16} \text{ s}$	(A1)

Question	Answer	Marks
2(d)(i)	$E \propto Q / r^2$	C1
	ratio = $[1.60 \times 10^{-19} \times (170 \times 10^{-12})^2] / [3.2 \times 10^{-19} \times (340 \times 10^{-12})^2]$ = 0.13	A1
2(d)(ii)	resultant force slightly less (than 1.6×10^{-8} N) so speed lower or resultant force slightly less (than 1.6×10^{-8} N) so period greater	B1

Question	Answer	Marks
3(a)	(thermal) energy per unit mass (to cause state change)	B1
	(thermal) energy to change state at constant temperature	B1
3(b)	(for vaporisation): involves greater change in volume (of substance) or involves greater increase in separation of molecules	B1
	more work has to be done by molecules (to separate) or greater increase in potential energy of molecules	M1
	kinetic energy of molecules unchanged, so more thermal energy needed	A1
3(c)	$Q = mc\Delta\theta$ and $Q = mL$	C1
	$\Delta\theta$ for the water = 26.4 – 10.3	C1
	$(37.0 \times L) + (37.0 \times 4.18 \times 10.3) = (208 \times 4.18 \times 16.1)$	C1
	$L = 335 \text{ J g}^{-1}$	A1

Question	Answer	Marks							
4(a)(i)	sum of potential energy and kinetic energy	B1							
	(total) energy of random motion of particles	B1							
4(a)(ii)	potential energy (of molecules) (in an ideal gas) is zero, so the internal energy of the gas is equal to the total kinetic energy (of molecules)	B1							
	kinetic energy of molecules is proportional to (thermodynamic) temperature (so internal energy is proportional to (thermodynamic) temperature))	B1							
4(b)	cooling work done = 0	B1							
	compression increase in internal energy = $+2U$	B1							
	cooling change in internal energy = $-U$	B1							
	both rows: thermal energy adds to work to give increase in internal energy in terms of U and/or W (if fully correct, thermal energy for compression = $2U - W$ and thermal energy for cooling = $-U$: <table border="1"><tr><td>compression</td><td>$+W$</td><td>$2U - W$</td><td>$+2U$</td></tr><tr><td>cooling</td><td>0</td><td>$-U$</td><td>$-U$</td></tr></table>)	compression	$+W$	$2U - W$	$+2U$	cooling	0	$-U$	$-U$
compression	$+W$	$2U - W$	$+2U$						
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Question	Answer	Marks
5(a)(i)	amplitude = 0.60 m	A1
5(a)(ii)	oscillations are simple harmonic	B1
5(b)	<i>Any three points from:</i> • mean / equilibrium position is at $h = 1.4$ m • total energy of oscillations = 9.0 J • angular frequency of oscillations = 1.2 rad s^{-1} or period of oscillations = 5.1 s or frequency of oscillation = 0.19 Hz • maximum speed of block = 0.73 m s^{-1} • mass of block = 33 kg	B3
5(c)	U-shaped curve resting on h axis (with minimum at $E_P = 0$)	B1
	curve from $h = 0.8$ m to $h = 2.0$ m, with minimum E_P shown at $h = 1.4$ m	B1
	both end-points of curve shown at $E_P = 9.0$ J	B1

Question	Answer	Marks
6(a)(i)	conversion from a.c. to d.c.	B1
6(a)(ii)	smoothing	B1
6(b)(i)	$A = 12 \text{ V}$	A1
	$B = 2\pi / (20 \times 10^{-3})$ $= 310 \text{ rad s}^{-1}$	A1
6(b)(ii)	full-wave (rectification)	B1
6(b)(iii)	four diodes shown, with correct circuit symbols	B1
	four diodes correctly connected to form a bridge rectifier	B1
6(b)(iv)	$V = V_0 \exp(-t / \tau)$ or $V = V_0 \exp(-t / RC)$ and $\tau = RC$	C1
	$8.0 = 12 \exp(-7.3 \times 10^{-3} / \tau)$	C1
	$\tau = 0.018 \text{ s}$	A1
6(c)	time constant = RC	C1
	$R = (0.018 / 570 \times 10^{-6})$ $= 32 \Omega$	A1

Question	Answer	Marks
7(a)	• force per unit length • force per unit current • length / current perpendicular to field <i>1 mark for any two points, 2 marks for all three points.</i>	B2
7(b)(i)	$F = BQv$	B1
7(b)(ii)	arrow at Y pointing vertically upwards	B1
7(b)(iii)	upwards deflection showing circular path	B1
7(c)(i)	electric field applied vertically downwards (may be shown on a labelled diagram)	B1
	electric force on particle in opposite direction to magnetic force (may be shown on a labelled diagram)	B1
	particle undeflected when magnitudes of electric and magnetic forces are equal	B1
7(c)(ii)	$EQ = BQv$	B1
	$v = E / B$	A1

Question	Answer	Marks
8(a)	wavelength associated with a moving particle	B1
8(b)	$\lambda = h / p$	C1
	$= (6.63 \times 10^{-34}) / (9.11 \times 10^{-31} \times 4.9 \times 10^7)$ $= 1.5 \times 10^{-11} \text{ m}$	A1
8(c)	similarity: <i>any one point from:</i> • same mass • same <u>magnitude</u> of charge • both leptons	B1
	difference: <i>any one point from:</i> • electron has negative charge, positron has positive charge • positron is anti-particle of electron • electron is a particle, positron is an anti-particle	B1
8(d)(i)	(pair) annihilation	B1
8(d)(ii)	their mass gets converted into energy	B1
	(their mass–energy) becomes the energy of the gamma photons	B1
8(d)(iii)	they travel in opposite directions to conserve momentum	B1
8(d)(iv)	kinetic energy = $\frac{1}{2} \times 9.11 \times 10^{-31} \times (4.9 \times 10^7)^2 = 1.1 \times 10^{-15} \text{ J}$	A1

Question	Answer	Marks
8(d)(v)	$E = mc^2$	C1
	$E = hc / \lambda$ or $E = hf$ and $c = f\lambda$	C1
	$(1.1 \times 10^{-15}) + (9.11 \times 10^{-31} \times (3.00 \times 10^8)^2) = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$ $\lambda = 2.39 \times 10^{-12} \text{ m}$	A1

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Question	Answer	Marks
9(a)	number of nuclear disintegrations per unit time	B1
9(b)	activity is proportional to the number of undecayed nuclei	B1
	activity = $(-)$ rate of change of number of undecayed nuclei	B1
	N is proportional to the rate of change of N (so exponential variation)	B1
9(c)(i)	$120 = 180 \exp(-\lambda \times 8.4)$	C1
	$\lambda = 0.048 \text{ min}^{-1}$	A1
9(c)(ii)	half-life = $\ln 2 / 0.048$ = 14 min	A1
9(c)(iii)	line with negative gradient throughout, starting at (0, 180)	B1
	curve with negative gradient passing through (8.4, 120)	B1
	curve with decreasing negative gradient, from $t = 0$ to $t = 24$ min, passing through (14, 90)	B1

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Question	Answer	Marks
10(a)	speed is (directly) proportional to distance	M1
	speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer	A1
10(b)(i)	galaxy is receding from the Earth	B1
	observed wavelength is redshifted from emitted wavelength	B1
10(b)(ii)	$\Delta\lambda / \lambda = v / c$ $(4.91 - 4.62) / 4.62 = v / (3.00 \times 10^8)$	C1
	$v = 1.9 \times 10^7 \text{ m s}^{-1}$	A1
10(b)(iii)	wavelength (of maximum intensity) is inversely proportional to temperature	B1
	observed wavelength too high, so determined temperature too low	B1
10(c)	$v = H_0 d$	C1
	$d = (1.9 \times 10^7) / (2.3 \times 10^{-18})$ $= 8.3 \times 10^{24} \text{ m}$	A1

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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.

Question	Answer	Marks
1(a)	angle (subtended at centre of a circle) when arc (length) = radius	B1
1(b)(i)	$v = r\omega$	C1
	$\omega = 17 / 0.46$ $= 37 \text{ rad s}^{-1}$	A1
1(b)(ii)	$T = 2\pi r / v$ or $T = 2\pi / \omega$	C1
	$= 2\pi \times 0.46 / 17$ or $2\pi / 37$ $= 0.17 \text{ s}$	A1
1(b)(iii)	distance = $2\pi \times 0.038 = 0.24 \text{ m}$	A1
1(b)(iv)	angle = arc length / radius	C1
	$= 0.24 / 0.15$ $= 1.6 \text{ rad}$	A1
1(c)	point X moves through a smaller distance in the same time or (linear) speed of movement of point X / chain decreases or (linear) speed of (circumference of) both cogs decreases	B1
	angular speed (of pedals) decreases	B1

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Question	Answer	Marks
2(a)(i)	direction of force	B1
	force acting on a (test) mass	B1
2(a)(ii)	at least four radial lines from the Earth's surface, equally spaced around the surface	B1
	arrows indicating direction towards Earth	B1
2(b)(i)	top pole labelled S and bottom pole labelled N	B1
2(b)(ii)	solenoid field pattern at the poles: at least two field lines either side of both poles, close to the poles, clustered closely together, leaving the surface approximately perpendicularly to the surface and curving away from the axis of the poles as their distance from the surface increases	B1
	solenoid field pattern above the equator: at least one field line either side of the Earth connecting two points on the surface that are on the same side of the poles, one north of the equator and one south of it, passing above the surface near the magnetic equator approximately parallel to the surface	B1
2(c)(i)	(around the surface) lines are evenly spaced	B1
	all lines perpendicular to surface or pointing down towards surface (at all points around the surface)	B1

Question	Answer	Marks
2(c)(ii)	<i>Any three bulleted points from:</i> • strongest at the poles • weakest near the Equator <i>Up to two points from:</i> • perpendicular to surface at the poles • parallel to the surface near the Equator • angle to surface increases from Equator to poles	B3

Question	Answer	Marks
3(a)	(thermal) energy per unit mass (to cause temperature change)	B1
	(thermal) energy per unit change in temperature	B1
3(b)(i)	density = mass / volume	C1
	$\text{mass} = 2.700 \times 10^3 \times 3.612 \times 10^{-3}$ $= 9.752 \text{ kg}$	A1
3(b)(ii)	$\text{volume} = 3.612 \times 10^{-3} \times (2.700 / 2.620) = 3.722 \times 10^{-3} \text{ m}^3$ or $\text{volume} = 9.752 / (2.620 \times 10^3) = 3.722 \times 10^{-3} \text{ m}^3$	A1

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Question	Answer	Marks
3(b)(iii)	$W = p\Delta V$	C1
	$= 1.01 \times 10^5 \times (3.722 - 3.612) \times 10^{-3}$	A1
	$= 11.1 \text{ J}$	
3(b)(iv)	volume (of block) increases	B1
	work is done against the atmosphere so work done (on block) is negative	B1
3(b)(v)	thermal energy $= (4.38 \times 10^6) + 11.1$	B1
	specific heat capacity $= (4.38 \times 10^6) / (9.75 \times 500)$	C1
	$= 898 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}$	A1
3(c)	work done is negligible compared with (change in) internal energy so (answer in (b)(v) would be) unchanged	B1

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Question	Answer	Marks
4(a)(i)	thermodynamic temperature	B1
4(a)(ii)	molar gas constant	B1
4(b)(i)	m : mass of one molecule (of the gas)	B1
	$\langle c^2 \rangle$: mean-square speed (of molecules)	B1
4(b)(ii)	$NBT / A = \frac{1}{3} Nm \langle c^2 \rangle$	M1
	clear use of $E_K = \frac{1}{2} m \langle c^2 \rangle$ leading to $E_K = 3BT / 2A$	A1
4(c)	line with positive gradient passing through the origin	B1
	smooth curve with decreasing positive gradient	B1

Question	Answer	Marks
5(a)	(motion in which) acceleration is (directly) proportional to displacement	B1
	(motion in which) acceleration is (always) in the opposite <u>direction</u> to displacement or acceleration is (always) directed towards a fixed point	B1
5(b)(i)	period = $2\pi / 16$ = 0.39 s	A1
5(b)(ii)	$v_0 = \omega x_0$ or $v_0 = \omega \sqrt{x_0^2 - 0^2}$	C1
	$x_0 = 0.56 / 16$ = 0.035 m	A1
5(b)(iii)	$v = \pm 16 \sqrt{0.0352 - x^2}$	A1
5(b)(iv)	closed loop surrounding the origin	B1
	loop crosses $v = 0$ at maximum values of x at $x = \pm 3.5$ cm	B1
	loop crosses $x = 0$ at maximum values of v at $v = \pm 0.56$ m s ⁻¹	B1

Question	Answer	Marks
6(a)	plate X marked as negative and plate Y marked as positive	B1
6(b)(i)	$E = V / x$	C1
	$= (58 \times 10^3) / 0.041$	A1
	$= 1.4 \times 10^6 \text{ N C}^{-1}$	
6(b)(ii)	$ma = eE$	C1
	$a = (1.60 \times 10^{-19} \times 1.41 \times 10^6) / (9.11 \times 10^{-31})$	A1
	$= 2.5 \times 10^{17} \text{ m s}^{-2}$	
6(c)(i)	$eV = hc / \lambda$ or $eV = hf$ and $f = c / \lambda$	C1
	$(1.60 \times 10^{-19} \times 58 \times 10^3) = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$	M1
	clear conversion from m to pm leading to $\lambda = 21 \text{ pm}$	A1
6(c)(ii)	X-rays	B1
6(c)(iii)	Any two points from: - waves are passed into structure and transmitted waves detected - different parts of the structure absorb different fractions of energy - difference in detected / transmitted <u>intensities</u> used (to form image)	B2

Question	Answer	Marks
7(a)	$V_C = V_R$	B1
7(b)(i)	$C = Q / V$	C1
	$= (7.2 \times 10^{-3}) / 12 \quad (= 6.0 \times 10^{-4} \text{ F})$	A1
	$= 600 \mu\text{F}$	
7(b)(ii)	$R = V / I$	C1
	$= 12 / (1.5 \times 10^{-3}) \quad (= 8000 \Omega)$	A1
	$= 8.0 \text{ k}\Omega$	
7(b)(iii)	$\tau = RC$	C1
	$= 8000 \times 6.0 \times 10^{-4}$	A1
	$= 4.8 \text{ s}$	
7(c)	<i>Any two points from:</i> - charge and current are both (directly) proportional to voltage - charge is (directly) proportional to current - current is the rate of change of charge	B2
	Q is proportional to the rate of change of Q (so exponential variation)	B1

Question	Answer	Marks
8(a)(i)	half-wave (rectification)	B1
8(a)(ii)	$V_0 = 6.0 \times \sqrt{2}$ $= 8.5 \text{ V}$	A1
8(b)(i)	$P = V^2 / R$	C1
	$P_0 = 8.5^2 / 45$ $= 1.6 \text{ W}$	A1
8(b)(ii)	two humps of width $0.5T$ and two sections of zero power of width $0.5T$	B1
	all humps drawn have width $0.5T$, minima at $P = 0$ and peaks at $P = P_0$	B1
	correct sinusoidal shape, with smooth troughs sitting on t -axis at $P = 0$	B1
8(b)(iii)	mean power within each hump is $\frac{1}{2}P_0$ from the symmetry of the curve	B1
	additional half factor from removal of half of the power in each cycle	B1
8(b)(iv)	$\langle P \rangle = V_{\text{r.m.s.}}^2 / R$ $V_{\text{r.m.s.}} = \sqrt{[(1.6 / 4) \times 45]}$ $= 4.2 \text{ V}$	A1

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Question	Answer	Marks
9(a)	emission of electrons (from a metal surface)	B1
	when electromagnetic radiation is incident (on surface / electrons)	B1
9(b)(i)	current falls to zero when applied voltage equals energy per unit charge of emitted electrons	B1
	energy of photon depends on frequency	B1
	maximum energy of electron depends on energy of photon	B1
9(b)(ii)	<i>Any three points from:</i> • threshold frequency = 1.5×10^{15} Hz • threshold wavelength = 2.0×10^{-7} m • work function = 6.2 eV (or 9.9×10^{-19} J) • Planck constant = 6.6×10^{-34} J s (not 6.63×10^{-34} J s) • number per unit time (of photons / electrons) = $1.7 \times 10^{16} \text{ s}^{-1}$ (in stage 1) • power of incident radiation = 0.028 W (in stage 1)	B3

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Question	Answer	Marks															
10(a)	(decay is) not affected by external / environmental factors	B1															
10(b)(i)	half-life of X = $2T$ and half-life of Y = $3T$	B1															
	both samples show decay constant, in terms of $1 / T$, equal to $\ln 2 / \text{half-life}$ (decay constant of X = $\ln 2 / 2T$ and decay constant of Y = $\ln 2 / 3T$ if both half-lives correct)	B1															
	both samples show N_0 , in terms of AT , equal to initial activity / decay constant (N_0 for X = $8AT / \ln 2$ and N_0 for Y = $3AT / \ln 2$ if both decay constants correct) (Fully correct table: <table><tr><td></td><td>half-life</td><td>decay constant</td><td>A_0</td><td>N_0</td></tr><tr><td>X</td><td>$2T$</td><td>$\ln 2 / 2T$</td><td>$4A$</td><td>$8AT / \ln 2$</td></tr><tr><td>Y</td><td>$3T$</td><td>$\ln 2 / 3T$</td><td>A</td><td>$3AT / \ln 2$</td></tr></table>)		half-life	decay constant	A_0	N_0	X	$2T$	$\ln 2 / 2T$	$4A$	$8AT / \ln 2$	Y	$3T$	$\ln 2 / 3T$	A	$3AT / \ln 2$	B1
		half-life	decay constant	A_0	N_0												
X	$2T$	$\ln 2 / 2T$	$4A$	$8AT / \ln 2$													
Y	$3T$	$\ln 2 / 3T$	A	$3AT / \ln 2$													
10(b)(ii)	correct substitution of A_0 and λ into $A_0 \exp (-\lambda t)$ for sample X or sample Y	C1															
	$4A \exp (-t \ln 2 / 2T) = A \exp (-t \ln 2 / 3T)$	C1															
	$t = 12T$	A1															
10(c)	<i>Any two points from:</i> • (radiation) emitted in all directions, not just in direction of detector • some radiation absorbed by air / sample / window of detector • some radiation may not register even though it reaches detector	B2															

Cambridge International AS & A Level

PHYSICS**9702/43**

Paper 4 A Level Structured Questions

May/June 2025

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2025 series for most Cambridge IGCSE, Cambridge International A and AS Level components, and some Cambridge O Level components.

This document consists of **19** printed pages.

PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptions for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors 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
	arithmetic error
	benefit of the doubt given
	contradiction in response, mark not awarded
	correct point or mark awarded
	error carried forward applied
	error in number of significant figures
	incorrect or insufficient point ignored while marking the rest of the response
	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

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.

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.

Question	Answer	Marks
1(a)	work done per unit mass	B1
	work (done in) moving mass from infinity (to the point)	B1
1(b)(i)	evidence of addition of 3.4×10^6 to 1.7×10^6 or 6.8×10^6	C1
	$GM \times 122 / (5.1 \times 10^6)$ or $GM \times 122 / (10.2 \times 10^6)$	C1
	$6.67 \times 10^{-11} \times M \times 122 \times [(5.1 \times 10^6)^{-1} - (10.2 \times 10^6)^{-1}] = 5.1 \times 10^8$	A1
	leading to $M = 6.4 \times 10^{23}$ kg	
1(b)(ii)	$\phi = (-) (6.67 \times 10^{-11} \times 6.4 \times 10^{23}) / (3.4 \times 10^6)$	C1
	$= -1.3 \times 10^7 \text{ J kg}^{-1}$	A1
1(c)(i)	Mars takes (just under) 25 hours to rotate once on its axis	B1
1(c)(ii)	orbit is equatorial or orbit is in same direction as direction of rotation of Mars	B1

Question	Answer	Marks
2(a)	(electric) force is (directly) proportional to product of charges	B1
	force (between point charges) is inversely proportional to the square of their separation	B1
2(b)(i)	charge = $(+)2e$	A1
2(b)(ii)	$F = 2 \times (1.60 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (170 \times 10^{-12})^2] = 1.6 \times 10^{-8} \text{ N}$	A1
2(c)(i)	$F = mv^2 / r$	C1
	$v = [(1.6 \times 10^{-8} \times 170 \times 10^{-12}) / (9.11 \times 10^{-31})]^{1/2}$ $= 1.7 \times 10^6 \text{ m s}^{-1}$	A1
2(c)(ii)	$F = mr\omega^2$ and $\omega = 2\pi / T$ $F = 4\pi^2 mr / T^2$	C1
	$T = [(4\pi^2 \times 9.11 \times 10^{-31} \times 170 \times 10^{-12}) / (1.6 \times 10^{-8})]^{1/2}$ $= 6.2 \times 10^{-16} \text{ s}$	A1
	or	
	$v = 2\pi r / T$	(C1)
	$T = (2\pi \times 170 \times 10^{-12}) / (1.73 \times 10^6)$ $= 6.2 \times 10^{-16} \text{ s}$	(A1)

Question	Answer	Marks
2(d)(i)	$E \propto Q / r^2$	C1
	ratio = $[1.60 \times 10^{-19} \times (170 \times 10^{-12})^2] / [3.2 \times 10^{-19} \times (340 \times 10^{-12})^2]$ = 0.13	A1
2(d)(ii)	resultant force slightly less (than 1.6×10^{-8} N) so speed lower or resultant force slightly less (than 1.6×10^{-8} N) so period greater	B1

Question	Answer	Marks
3(a)	(thermal) energy per unit mass (to cause state change)	B1
	(thermal) energy to change state at constant temperature	B1
3(b)	(for vaporisation): involves greater change in volume (of substance) or involves greater increase in separation of molecules	B1
	more work has to be done by molecules (to separate) or greater increase in potential energy of molecules	M1
	kinetic energy of molecules unchanged, so more thermal energy needed	A1
3(c)	$Q = mc\Delta\theta$ and $Q = mL$	C1
	$\Delta\theta$ for the water = 26.4 – 10.3	C1
	$(37.0 \times L) + (37.0 \times 4.18 \times 10.3) = (208 \times 4.18 \times 16.1)$	C1
	$L = 335 \text{ J g}^{-1}$	A1

Question	Answer	Marks							
4(a)(i)	sum of potential energy and kinetic energy	B1							
	(total) energy of random motion of particles	B1							
4(a)(ii)	potential energy (of molecules) (in an ideal gas) is zero, so the internal energy of the gas is equal to the total kinetic energy (of molecules)	B1							
	kinetic energy of molecules is proportional to (thermodynamic) temperature (so internal energy is proportional to (thermodynamic) temperature))	B1							
4(b)	cooling work done = 0	B1							
	compression increase in internal energy = $+2U$	B1							
	cooling change in internal energy = $-U$	B1							
	both rows: thermal energy adds to work to give increase in internal energy in terms of U and/or W (if fully correct, thermal energy for compression = $2U - W$ and thermal energy for cooling = $-U$: <table><tr><td>compression</td><td>$+W$</td><td>$2U - W$</td><td>$+2U$</td></tr><tr><td>cooling</td><td>0</td><td>$-U$</td><td>$-U$</td></tr></table>)	compression	$+W$	$2U - W$	$+2U$	cooling	0	$-U$	$-U$
compression	$+W$	$2U - W$	$+2U$						
cooling	0	$-U$	$-U$						

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Question	Answer	Marks
5(a)(i)	amplitude = 0.60 m	A1
5(a)(ii)	oscillations are simple harmonic	B1
5(b)	<i>Any three points from:</i> • mean / equilibrium position is at $h = 1.4$ m • total energy of oscillations = 9.0 J • angular frequency of oscillations = 1.2 rad s^{-1} or period of oscillations = 5.1 s or frequency of oscillation = 0.19 Hz • maximum speed of block = 0.73 m s^{-1} • mass of block = 33 kg	B3
5(c)	U-shaped curve resting on h axis (with minimum at $E_P = 0$)	B1
	curve from $h = 0.8$ m to $h = 2.0$ m, with minimum E_P shown at $h = 1.4$ m	B1
	both end-points of curve shown at $E_P = 9.0$ J	B1

Question	Answer	Marks
6(a)(i)	conversion from a.c. to d.c.	B1
6(a)(ii)	smoothing	B1
6(b)(i)	$A = 12 \text{ V}$	A1
	$B = 2\pi / (20 \times 10^{-3})$ $= 310 \text{ rad s}^{-1}$	A1
6(b)(ii)	full-wave (rectification)	B1
6(b)(iii)	four diodes shown, with correct circuit symbols	B1
	four diodes correctly connected to form a bridge rectifier	B1
6(b)(iv)	$V = V_0 \exp(-t / \tau)$ or $V = V_0 \exp(-t / RC)$ and $\tau = RC$	C1
	$8.0 = 12 \exp(-7.3 \times 10^{-3} / \tau)$	C1
	$\tau = 0.018 \text{ s}$	A1
6(c)	time constant = RC	C1
	$R = (0.018 / 570 \times 10^{-6})$ $= 32 \Omega$	A1

Question	Answer	Marks
7(a)	• force per unit length • force per unit current • length / current perpendicular to field <i>1 mark for any two points, 2 marks for all three points.</i>	B2
7(b)(i)	$F = BQv$	B1
7(b)(ii)	arrow at Y pointing vertically upwards	B1
7(b)(iii)	upwards deflection showing circular path	B1
7(c)(i)	electric field applied vertically downwards (may be shown on a labelled diagram)	B1
	electric force on particle in opposite direction to magnetic force (may be shown on a labelled diagram)	B1
	particle undeflected when magnitudes of electric and magnetic forces are equal	B1
7(c)(ii)	$EQ = BQv$	B1
	$v = E / B$	A1

Question	Answer	Marks
8(a)	wavelength associated with a moving particle	B1
8(b)	$\lambda = h / p$	C1
	$= (6.63 \times 10^{-34}) / (9.11 \times 10^{-31} \times 4.9 \times 10^7)$ $= 1.5 \times 10^{-11} \text{ m}$	A1
8(c)	similarity: <i>any one point from:</i> • same mass • same <u>magnitude</u> of charge • both leptons	B1
	difference: <i>any one point from:</i> • electron has negative charge, positron has positive charge • positron is anti-particle of electron • electron is a particle, positron is an anti-particle	B1
8(d)(i)	(pair) annihilation	B1
8(d)(ii)	their mass gets converted into energy	B1
	(their mass–energy) becomes the energy of the gamma photons	B1
8(d)(iii)	they travel in opposite directions to conserve momentum	B1
8(d)(iv)	kinetic energy = $\frac{1}{2} \times 9.11 \times 10^{-31} \times (4.9 \times 10^7)^2 = 1.1 \times 10^{-15} \text{ J}$	A1

Question	Answer	Marks
8(d)(v)	$E = mc^2$	C1
	$E = hc / \lambda$ or $E = hf$ and $c = f\lambda$	C1
	$(1.1 \times 10^{-15}) + (9.11 \times 10^{-31} \times (3.00 \times 10^8)^2) = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$ $\lambda = 2.39 \times 10^{-12} \text{ m}$	A1

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Question	Answer	Marks
9(a)	number of nuclear disintegrations per unit time	B1
9(b)	activity is proportional to the number of undecayed nuclei	B1
	activity = $(-)$ rate of change of number of undecayed nuclei	B1
	N is proportional to the rate of change of N (so exponential variation)	B1
9(c)(i)	$120 = 180 \exp(-\lambda \times 8.4)$	C1
	$\lambda = 0.048 \text{ min}^{-1}$	A1
9(c)(ii)	half-life = $\ln 2 / 0.048$ = 14 min	A1
9(c)(iii)	line with negative gradient throughout, starting at (0, 180)	B1
	curve with negative gradient passing through (8.4, 120)	B1
	curve with decreasing negative gradient, from $t = 0$ to $t = 24$ min, passing through (14, 90)	B1

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Question	Answer	Marks
10(a)	speed is (directly) proportional to distance	M1
	speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer	A1
10(b)(i)	galaxy is receding from the Earth	B1
	observed wavelength is redshifted from emitted wavelength	B1
10(b)(ii)	$\Delta\lambda / \lambda = v / c$	C1
	$(4.91 - 4.62) / 4.62 = v / (3.00 \times 10^8)$	
	$v = 1.9 \times 10^7 \text{ m s}^{-1}$	A1
10(b)(iii)	wavelength (of maximum intensity) is inversely proportional to temperature	B1
	observed wavelength too high, so determined temperature too low	B1
10(c)	$v = H_0 d$	C1
	$d = (1.9 \times 10^7) / (2.3 \times 10^{-18})$	A1
	$= 8.3 \times 10^{24} \text{ m}$	

Cambridge International AS & A Level

PHYSICS**9702/44**

Paper 4 A Level Structured Questions

May/June 2025

MARK SCHEME

Maximum Mark: 100

Published

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Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2025 series for most Cambridge IGCSE, Cambridge International A and AS Level components, and some Cambridge O Level components.

This document consists of **19** printed pages.

PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptions for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors 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
	arithmetic error
	benefit of the doubt given
	contradiction in response, mark not awarded
	correct point or mark awarded
	error carried forward applied
	error in number of significant figures
	incorrect or insufficient point ignored while marking the rest of the response
	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

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.

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
1(a)	force per unit mass	B1
1(b)(i)	radial	B1
	towards (centre of) planet	B1
1(b)(ii)	(changes in) height (very) much smaller than radius	B1
	(radius + height) ² ≈ radius ² or field lines are approximately parallel	B1
1(c)(i)	$9.81 \times R^2 = 3.99 \times 10^{14}$	C1
	$R = 6.38 \times 10^6 \text{ m}$	A1
1(c)(ii)	gravitational potential = $-(GM/R)$ $= -(3.99 \times 10^{14}) / (6.38 \times 10^6)$	C1
	$= -6.25 \times 10^7 \text{ J kg}^{-1}$	A1
1(d)	potential (energy) zero at infinite separation	B1
	(gravitational) force is attractive	B1

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Question	Answer	Marks
2(a)	same temperature (as each other)	B1
	no net transfer of thermal energy (between them)	B1
2(b)(i)	$E_1 = XL$	B1
2(b)(ii)	$E_2 = Mc(t - \theta)$	A1
2(b)(iii)	$E_3 = Xc\theta$	B1
2(c)	$E_2 = E_1 + E_3$	C1
	$Mc(t - \theta) = XL + Xc\theta$ and completion of algebra to reach $\theta = (Mct - XL) / c(M + X)$	A1

Question	Answer	Marks
3(a)	(gas that obeys) $pV \propto T$ (at all values of p , V and T)	M1
	where T is thermodynamic temperature	A1
3(b)(i)	$pV = \frac{1}{3} Nm\langle c^2 \rangle$ and $Nm / V = \rho$ $(p = \frac{1}{3} \rho \langle c^2 \rangle)$	C1
	r.m.s. speed = $\sqrt{\langle c^2 \rangle}$	C1
	$1.6 \times 10^5 = \frac{1}{3} \times 1.9 \times \langle c^2 \rangle$ leading to r.m.s. speed = 500 m s^{-1} or r.m.s. speed = $\sqrt{(3 \times 1.6 \times 10^5 / 1.9)} = 500 \text{ m s}^{-1}$	A1
3(b)(ii)	$(pV =) \frac{1}{3} Nm\langle c^2 \rangle = NkT$ (so) $\frac{1}{2} m\langle c^2 \rangle = (3/2) kT$	C1
	$\frac{1}{2} \times 4.7 \times 10^{-26} \times 503^2 = (3/2) \times 1.38 \times 10^{-23} \times T$ $T = 290 \text{ K}$	A1
	or	
	$pV = NkT$ and $Nm / V = \rho$ (so) $T = pm / \rho k$	(C1)
	$T = 1.6 \times 10^5 \times 4.7 \times 10^{-26} / (1.9 \times 1.38 \times 10^{-23})$ $= 290 \text{ K}$	(A1)

Question	Answer	Marks
3(c)	potential energy (of molecules) is zero	B1
	$U = N \times \frac{1}{2} m \langle c^2 \rangle = 6.0 \times 6.02 \times 10^{23} \times \frac{1}{2} \times 4.7 \times 10^{-26} \times 503^2$ or $U = N \times \left(\frac{3}{2} \right) kT = 6.0 \times 6.02 \times 10^{23} \times \left(\frac{3}{2} \right) \times 1.38 \times 10^{-23} \times 287$ or $U = n \times \left(\frac{3}{2} \right) RT = 6.0 \times \left(\frac{3}{2} \right) \times 8.31 \times 287$	C1
	$U = 21000 \text{ J}$	A1

Question	Answer	Marks
4(a)	(motion in which) acceleration is (directly) proportional to displacement	B1
	(motion in which) acceleration is (always) in the opposite <u>direction</u> to displacement or acceleration is (always) directed towards a fixed point	B1
4(b)(i)	t_1 and t_5 or t_3 and t_7	B1
4(b)(ii)	$f = 1 / T$	C1
	period = $2.2 / 1.25$ $f = 1.25 / 2.2$ = 0.57 Hz	A1
4(c)	$v_0 = \omega x_0$ and $\omega = 2\pi f$	C1
	$0.080 = 2\pi \times 0.57 \times x_0$	C1
	$x_0 = 0.022$ m	A1

Question	Answer	Marks
5(a)	work done per unit charge	B1
	work done (on charge) in moving positive charge from infinity (to the point)	B1
5(b)(i)	electric field strength inversely proportional to distance ²	C1
	$E = 3^2 \times 2.0 \times 10^5$ $= 1.8 \times 10^6 \text{ N C}^{-1}$	A1
5(b)(ii)	$V = Q / 4\pi\epsilon_0 r$ and $E = Q / 4\pi\epsilon_0 r^2$ (so $E = V / r$)	B1
	$r = (9.0 \times 10^4) / (1.8 \times 10^6) = 0.050 \text{ m} = 5.0 \text{ cm}$	A1
5(b)(iii)	$Q = 4\pi\epsilon_0 Vr$ $= 4\pi \times 8.85 \times 10^{-12} \times 9.0 \times 10^4 \times 0.050$	C1
	$= 5.0 \times 10^{-7} \text{ C}$	A1
5(b)(iv)	$C = Q / V$	C1
	$= (5.0 \times 10^{-7}) / (9.0 \times 10^4)$ $= 5.6 \times 10^{-12} \text{ F}$	A1

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Question	Answer	Marks
6(a)(i)	$F = BIL$	C1
	force on QR = $5.2 \times 10^{-3} \times 1.2 \times 0.054 \times 190$	C1
	= 0.064 N	A1
6(a)(ii)	torque = force $\times$ perpendicular distance between forces	C1
	= $0.064 \times 0.025 \cos \theta = (1.6 \times 10^{-3}) \cos \theta$ N m	A1
6(a)(iii)	one complete cycle of a sinusoidal curve between 0 and 360°	B1
	τ axis labelled to show maximum and minimum torques at $\pm 1.6 \times 10^{-3}$ N m	B1
	maximum at 0 and 360° and minimum at 180° (or vice versa), with torque shown as zero at 90° and 270°	B1
6(b)	(ferrous core) increases magnetic flux density	B1
	amplitude of torque increases	B1

Question	Answer	Marks
7(a)(i)	loss of energy (of oscillations)	B1
	due to resistive forces	B1
7(a)(ii)	amplitude (of oscillations) decreases gradually or oscillations continue (for several periods)	B1
7(a)(iii)	cutting of (magnetic) flux causes induced e.m.f. (in coil) or induced e.m.f. causes current (in resistor / circuit)	B1
	current causes dissipation of thermal energy in resistor or current in resistor causes dissipation of thermal energy	B1
	thermal energy comes from energy of oscillations	B1
7(b)	(for any given e.m.f.) current is lower so thermal energy dissipated at a lower rate or (for any given e.m.f.) current is lower so the resistive force is lower	B1
	oscillations are less damped or smaller decrease in amplitude of oscillations (in each period) or oscillations continue for longer	B1

Question	Answer	Marks
8(a)	four diodes shown (one in each gap) with correct circuit symbols	B1
	all four diodes connected in correct direction (pointing left to right)	B1
8(b)(i)	three lines showing exponential decay from the peaks at $0.5T$, $1.0T$ and $1.5T$, ending at the point where the decay meets the next rising peak	B1
	three curved lines rising along the upwards dotted lines from the minima to the peaks at $1.0T$, $1.5T$ and $2.0T$	B1
	minimum V at $(2/3) V_0$	B1
8(b)(ii)	from graph: discharge time (from V_0 to $(2/3)V_0$) = $(11/30) T$	C1
	$(2/3) V_0 = V_0 \exp(- (11/30)T/\tau)$	C1
	$\ln(2/3) = - 11T/30\tau$	A1
	$\tau = 0.90 T$	
8(b)(iii)	time constant is increased	B1
	line shows a larger minimum voltage or smaller difference between maximum and minimum voltages	B1

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Question	Answer	Marks
9(a)(i)	electromagnetic wave can behave like a particle	B1
	moving particle can behave like a wave	B1
9(a)(ii)	$\lambda = h / p$	M1
	h is the Planck constant	A1
9(b)(i)	<i>Any two points from:</i> • pattern similar to diffraction of light • diffraction (pattern) is characteristic of wave behaviour • rings show constructive and destructive interference	B2
9(b)(ii)	(de Broglie) wavelength decreases	B1
	rings become closer together	B1

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Question	Answer	Marks
10(a)	alternating p.d. (applied to crystal) makes crystal vibrate	B1
	when frequency of applied p.d. equals natural frequency of crystal, crystal resonates	B1
	natural frequency of crystal is in ultrasound range	B1
10(b)(i)	product of density and speed	M1
	speed is speed of ultrasound in medium (and density of medium)	A1
10(b)(ii)	(α is close to) 0 when Z_1 and Z_2 are equal	B1
	(α is close to) 1 when Z_1 and Z_2 are very different	B1
10(c)	$I = I_0 \exp(-\mu x)$	C1
	$\ln(I/I_0) = -\mu x$	A1
	$\ln 0.62 = -\mu \times 2.1$	
	$\mu = 0.23 \text{ cm}^{-1}$	

Question	Answer	Marks
11(a)(i)	(nuclear) fusion	B1
11(a)(ii)	$\Delta m = [0.030377 - (3 \times 0.002388)] \text{ u}$ $(= 0.023213 \text{ u})$	B1
	$E = \Delta m c^2$	C1
	$= 0.023213 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 = 3.47 \times 10^{-12} \text{ J}$	A1
11(b)(i)	mass of 1 mol of helium-4 = 4 g or mass of 1 helium atom = 4 u	C1
	$N \text{ rate} = (6.02 \times 10^{23} \times 7.34 \times 10^{11}) / (4 \times 10^{-3})$ or $N \text{ rate} = (7.34 \times 10^{11}) / (4 \times 1.66 \times 10^{-27})$	C1
	luminosity = $1.10 \times 10^{38} \times 3.47 \times 10^{-12}$ $= 3.83 \times 10^{26} \text{ W}$	A1
11(b)(ii)	$L = 4\pi\sigma r^2 T^4$ $3.83 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times (6.96 \times 10^8)^2 \times T^4$	C1
	$T = 5770 \text{ K}$	A1