



Cambridge International AS & A Level

PHYSICS

9702/41

Paper 4 A Level Structured Questions

May/June 2023

MARK SCHEME

Maximum Mark: 100

Published

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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 descriptors 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.

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>method</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)(i)	force per unit mass	B1
1(a)(ii)	force per unit positive charge	B1
1(a)(iii)	similarity: - inversely proportional to distance (from point) - points of equal potential lie on concentric spheres - zero at infinite distance <i>Any point, 1 mark</i>	B1
	difference: - gravitational potential is (always) negative - electric potential can be positive or negative <i>Any point, 1 mark</i>	B1
1(b)(i)	$g = GM / r^2$	M1
	$E = Q / 4\pi\epsilon_0 r^2$	M1
	algebra showing the elimination of r leading to $M / Q = (1 / 4\pi G\epsilon_0) (g / E)$	A1
1(b)(ii)	$\alpha = 1 / (4\pi \times 6.67 \times 10^{-11} \times 8.85 \times 10^{-12}) = 1.35 \times 10^{20} \text{ (kg}^2 \text{ C}^{-2}\text{)}$ or $\alpha = (8.99 \times 10^9) / (6.67 \times 10^{-11}) = 1.35 \times 10^{20} \text{ (kg}^2 \text{ C}^{-2}\text{)}$	A1
1(c)(i)	$E = \alpha g Q / M$ $= (1.35 \times 10^{20} \times 9.81 \times 4.80 \times 10^5) / (5.98 \times 10^{24})$	C1
	$= 106 \text{ N C}^{-1}$ or 106 V m^{-1}	A1
1(c)(ii)	same (direction)	B1

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Question	Answer	Marks
2(a)	horizontal force on sphere causes centripetal acceleration	B1
	weight of sphere is (now) equal to vertical component of tension or horizontal and vertical components (of force) (now) combine to give greater tension (in spring)	B1
	greater tension in spring so greater extension of spring	B1
2(b)(i)	$r = 10.8 \times \sin 27^\circ = 4.9 \text{ cm}$	A1
2(b)(ii)	$T \cos \theta = mg$ or $T \cos \theta = W$ and $W = mg$	C1
	$T \cos 27^\circ = 0.29 \times 9.81$ leading to $T = 3.2 \text{ N}$	A1
2(b)(iii)	$\Delta T = 3.2 - (0.29 \times 9.81)$	C1
	$k = \Delta T / \Delta x$ $= [3.2 - (0.29 \times 9.81)] / [10.8 - 8.5]$ $= 0.15 \text{ N cm}^{-1}$	A1
2(c)(i)	centripetal acceleration $= (T \sin \theta) / m$ $= (3.2 \times \sin 27^\circ) / 0.29$	C1
	$= 5.0 \text{ m s}^{-2}$	A1

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Question	Answer	Marks
2(c)(ii)	$a = r\omega^2$ and $\omega = 2\pi / T$ or $a = v^2 / r$ and $v = 2\pi r / T$	C1
	$T = 2\pi \times \sqrt{(0.049 / 5.0)}$ $= 0.62 \text{ s}$	A1

Question	Answer	Marks
3(a)	no <u>net</u> thermal energy is transferred (between them)	B1
3(b)(i)	variation (of density with temperature) is linear or each temperature has a unique value of density	B1
3(b)(ii)	- variation (of density with temperature) is not linear - region where the density does not vary with temperature - different temperatures have the same density <i>Any two points, 1 mark each</i>	B2
3(c)(i)	boiling point = 80 °C	A1
3(c)(ii)	$Q = Pt$ and $t = 21 \text{ s}$ (thermal energy supplied = $810 \times 21 = 17000 \text{ J}$)	C1
	$c = Q / m\Delta\theta$	C1
	thermal energy absorbed by beaker = $42 \times 0.84 \times (80 - 25)$ (= 1940 J)	C1
	s.h.c. of liquid = $[(810 \times 21) - (42 \times 0.84 \times (80 - 25))] / [120 \times (80 - 25)]$ = $2.3 \text{ J g}^{-1} \text{ K}^{-1}$	A1
3(d)	sketch: straight diagonal line from 25 °C to 100 °C and then horizontal at 100 °C	B1
	straight diagonal line starting at 25 °C with gradient approximately half that of the original line	B1

Question	Answer	Marks															
4(a)	- particles are in (continuous) random motion - particles have negligible volume (compared with the gas) - negligible forces between particles (except during collisions) (all) collisions (perfectly) elastic - time of collision negligible (in comparison with time between collisions) <i>Any two points, 1 mark each</i>	B2															
4(b)(i)	(general starting equation) $pV = nRT$	C1															
	$T = (2pV / nR)$ where R is the (molar) gas constant	A1															
4(b)(ii)	sketch: straight vertical line XY from $(V, 2p)$ to (V, p)	B1															
	straight horizontal line YZ from (V, p) to $(2V, p)$	B1															
	curve with gradient increasing from Z to X from $(2V, p)$ to $(V, 2p)$	B1															
4(b)(iii)	XY work done on gas correct (= 0)	B1															
	ZX increase in internal energy correct (= 0)	B1															
	YZ work done on gas correct (= $-pV$)	B1															
	XY increase in internal energy such that the increase in internal energy column adds up to zero	B1															
	all three thermal energies transferred such that $\Delta U = q + w$ in each row (completely correct answer: <table><tr><td>change</td><td>ΔU</td><td>Q</td><td>w</td></tr><tr><td>X to Y</td><td>$-U$</td><td>$-U$</td><td>0</td></tr><tr><td>Y to Z</td><td>[$+U$]</td><td>$U + pV$</td><td>$-pV$</td></tr><tr><td>Z to X</td><td>0</td><td>$-W$</td><td>[$+W$]</td></tr></table>)	change	ΔU	Q	w	X to Y	$-U$	$-U$	0	Y to Z	[$+U$]	$U + pV$	$-pV$	Z to X	0	$-W$	[$+W$]
change	ΔU	Q	w														
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Y to Z	[$+U$]	$U + pV$	$-pV$														
Z to X	0	$-W$	[$+W$]														

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Question	Answer	Marks
5(a)(i)	correct circuit symbol for a diode shown correctly connected in series with the wires leading into and out of the dotted box	B1
5(a)(ii)	smoothing / V_{OUT} is smoothed	B1
5(b)(i)	frequency = $1 / 0.04$ = 25 Hz	A1
5(b)(ii)	$V = V_0 \exp(-t / RC)$ and $\tau = RC$ or $V = V_0 \exp(-t / \tau)$	C1
	$3.25 = 5.50 \exp(-0.020 / \tau)$ leading to $\tau = 0.038$ s	A1
5(b)(iii)	$\tau = RC$	C1
	capacitance = $0.038 / 14000$ = 2.7×10^{-6} F	A1
5(c)	V_{IN} has constant magnitude in both positive and negative directions	B1
	(so) V_{OUT} is (now) constant / V_{OUT} does not vary with time	B1

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Question	Answer	Marks
6(a)	a region where a force acts on	M1
	a current-carrying conductor or a <u>moving</u> charge or a magnetic material / magnetic pole	A1
6(b)	concentric circles around the wire	B1
	spacing between circles increases with distance from wire	B1
	arrows showing direction of field is clockwise	B1
6(c)(i)	$F = BIL$	C1
	force per unit length = BI $= 2.6 \times 10^{-3} \times 5.0$ $= 0.013 \text{ N m}^{-1}$	A1
6(c)(ii)	to the right	B1
6(c)(iii)	force (per unit length) has the same magnitude due to Newton's 3rd law	B1
	$0.013 = 1.5 \times 10^{-3} \times I$ current = 8.7 A	A1

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Question	Answer	Marks
7(a)	wavelength associated with a <u>moving</u> particle	B1
7(b)(i)	(electron) diffraction	B1
7(b)(ii)	beam spreads out indicating diffraction or light and dark regions indicate an interference pattern	B1
	electron beam is behaving as a wave	B1
7(c)(i)	central blob and concentric rings	B1
	rings closer together (than previously)	B1
7(c)(ii)	(greater p.d. so) electrons to have greater momentum	B1
	greater momentum so decrease in (de Broglie) wavelength	B1
	lower (de Broglie) wavelength (for same grating spacing in crystal) causes: smaller diffraction angle or smaller angle of intensity maxima (for each order) or decrease in fringe spacing in diffraction pattern	B1

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Question	Answer	Marks
8(a)(i)	specific acoustic impedance = $1200 \times 1400 = 1.68 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$	A1
8(a)(ii)	density of air shown in table as 1.29	A1
	speed of sound in tissue shown in table as 1540	A1
8(b)(i)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ $= (1680000 - 440)^2 / (1680000 + 440)^2$	C1
	$= 0.999$	A1
8(b)(ii)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ $= (1680000 - 1680000)^2 / (1680000 + 1680000)^2$ $= 0$	A1
8(c)	without gel, (almost) all of the (incident) ultrasound is reflected (from skin)	B1
	with gel, (almost) all of the (incident) ultrasound is transmitted (into the body)	B1

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Question	Answer	Marks
9(a)	time for activity (of sample) to halve	B1
9(b)	sketch: line with positive gradient starting at (0,0) and extending to $t = 80$ min	B1
	exponential curve, extending from $t = 0$ to $t = 80$ min, with gradient of steadily decreasing magnitude	B1
	line passing through (0,0), (20, $0.5N_0$) and (40, $0.75 N_0$)	B1
9(c)(i)	every (undecayed) nucleus has the same probability of decay	M1
	fewer (undecayed) nuclei remaining (with time), so fewer will decay (in a given time interval)	A1
9(c)(ii)	- sample emits in all directions but detector only captures emissions in one direction - some emissions are absorbed before reaching detector - some emissions are scattered within the sample - simultaneous arrival of multiple particles only registers once - some particles may reach detector but not cause ionisation <i>Any two points, 1 mark each</i>	B2
	measured count rate is less than the activity	B1

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)	$F = L / (4\pi d^2)$	C1
	$= (3.8 \times 10^{31}) / [4\pi \times (1.8 \times 10^{24})^2]$	A1
	$= 9.3 \times 10^{-19} \text{ W m}^{-2}$	
10(c)(i)	galaxy is moving away (from the Earth)	B1
	wavelength (of light from the galaxy) increased by the Doppler effect / due to redshift	B1
10(c)(ii)	$\Delta\lambda / \lambda = v / c$ $v = [(492 - 486) \times 3.00 \times 10^8] / 486$ $(v = 3.7 \times 10^6 \text{ m s}^{-1})$	C1
	$H_0 = v / d$	C1
	$= (3.7 \times 10^6) / (1.8 \times 10^{24})$ $= 2.1 \times 10^{-18} \text{ s}^{-1}$	A1



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- Incorrect responses should not be awarded credit but will still count towards ***n***.
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Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

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Abbreviations

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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)	(gravitational) force is (directly) proportional to product of masses	B1
	force (between point masses) is inversely proportional to the square of their separation	B1
1(b)	$GMm / R^2 = mR\omega^2$	M1
	$\omega = 2\pi / T$ <u>and</u> algebra leading to $4\pi^2 R^3 = GMT^2$	A1
	or	
	$GMm / R^2 = mv^2 / R$	(M1)
	$v = 2\pi R / T$ <u>and</u> algebra leading to $4\pi^2 R^3 = GMT^2$	(A1)
1(c)	$4\pi^2 \times R^3 = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 60 \times 60)^2$ $(R = 4.22 \times 10^7 \text{ m})$	C1
	$h = R - (6.37 \times 10^6)$	C1
	$h = (4.22 \times 10^7) - (6.37 \times 10^6)$ $= 3.6 \times 10^7 \text{ m}$	A1
1(d)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (24 \times 60 \times 60)$	A1
	$= 7.3 \times 10^{-5} \text{ rad s}^{-1}$	
1(d)(ii)	orbit is from east to west	B1
	orbit is not equatorial / orbit is polar	B1

Question	Answer	Marks
2(a)(i)	(gas that obeys) $pV \propto T$ (for all values of p, V and T)	M1
	where T is thermodynamic temperature	A1
2(a)(ii)	temperature = $-273.15\text{ }^{\circ}\text{C}$	A1
2(b)(i)	$pV = NkT$	C1
	$N = (1.37 \times 10^5 \times 0.640) / (1.38 \times 10^{-23} \times (227 + 273))$	C1
	$= 1.27 \times 10^{25}$	A1
2(b)(ii)	mass = $0.0424 / (1.27 \times 10^{25})$ $= 3.34 \times 10^{-27}\text{ kg}$	A1
2(b)(iii)	$\frac{1}{2}m\langle c^2 \rangle = (3/2)kT$	C1
	$3.34 \times 10^{-27} \times v^2 = 3 \times 1.38 \times 10^{-23} \times 500$	C1
	$v = 2490\text{ m s}^{-1}$	A1
	or	
	$pV = \frac{1}{3}(Nm) \langle c^2 \rangle$ <u>and</u> Nm = mass of gas	(C1)
	$0.0424 \times v^2 = 3 \times 1.37 \times 10^5 \times 0.640$	(C1)
	$v = 2490\text{ m s}^{-1}$	(A1)
2(c)	sketch: line from (0, 0) to (500, v)	B1
	line with decreasing positive gradient throughout	B1

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Question	Answer	Marks
3(a)	<u>change</u> in internal energy = work done + energy transfer by heating	C1
	<u>increase</u> in internal energy = work done <u>on</u> system + energy transferred <u>to</u> the system by heating	A1
3(b)(i)	AB change in internal energy: decrease	B1
	AB work done on gas: positive	B1
	BC change in internal energy: increase	B1
	BC work done on gas: zero	B1
3(b)(ii)	more work done by gas in CD than is done on gas in AB or (no work done on gas in BC and DA so) (overall) gas does work	B1
	(overall) change in internal energy is zero	B1
	(must be an overall) input of thermal energy	B1

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Question	Answer	Marks
4(a)(i)	$\omega = 2\pi f$	C1
	$f = 9.7 / 2\pi$	A1
	$= 1.5 \text{ Hz}$	
4(a)(ii)	amplitude = $\sqrt{11.6} = 3.4 \text{ cm}$	A1
4(a)(iii)	$a_0 = \omega^2 x_0$	C1
	$= 9.7^2 \times 3.4 \times 10^{-2}$	A1
	$= 3.2 \text{ m s}^{-2}$	
4(b)	sketch: straight line through the origin with negative gradient	B1
	line with negative gradient passing through $(+3.4, -a_0)$ and $(-3.4, +a_0)$	B1
	line with ends at $x = \pm 3.4 \text{ cm}$ and $a = \pm a_0$	B1
4(c)	sum of potential energy and kinetic energy is constant	B1
	at maximum displacement, kinetic energy is zero or at maximum displacement, potential energy is maximum	B1
	at zero displacement, kinetic energy is maximum or at zero displacement, potential energy is minimum	B1

Question	Answer	Marks
5(a)(i)	$Q_A = CV$	A1
5(a)(ii)	$E_A = \frac{1}{2}CV^2$	A1
5(b)(i)	some of the charge transfers to (the plates of) capacitor B	B1
	transfer is because the p.d.s across the capacitors are not equal or transfer stops when the p.d.s across the capacitors become equal	B1
5(b)(ii)	$V_A = V_B$	M1
	charge on A + charge on B = CV	M1
	$CV_B + 3CV_B = CV$ leading to $V_B = V/4$	A1
	or	
	$C_T = 4C$	(M1)
	$Q_T = CV$	(M1)
	$V_B = CV/4C = V/4$	(A1)
5(b)(iii)	$\Delta E = \frac{1}{2}CV^2 - nCV^2$, where n is a multiple that is less than $\frac{1}{2}$ or total final energy = $\frac{1}{2} \times 4C \times (V/4)^2$ $= \frac{1}{8}CV^2$	C1
	$\Delta E = \frac{1}{2}CV^2 - \frac{1}{8}CV^2$ $= \frac{3}{8}CV^2$	A1

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Question	Answer	Marks
6(a)(i)	product of (magnetic) flux density and area	M1
	area perpendicular to the (magnetic) field	A1
6(a)(ii)	flux = $B \times \pi r^2$ = $0.17 \times \pi \times 0.36^2$	C1
	= $6.9 \times 10^{-2} \text{ Wb}$	A1
6(b)	time for one revolution = $1 / 25 \text{ s}$	C1
	e.m.f. = rate of cutting flux or $\Delta \Phi / \Delta t$	C1
	= 0.069×25 = 1.7 V	A1
6(c)	current (in disc) is perpendicular to magnetic field or current causes force to act on disc	B1
	force opposes rotation of disc	B1
	left-hand rule indicates current is from rim to axle	B1

Question	Answer	Marks
7(a)(i)	full-wave (rectification)	B1
7(a)(ii)	lower left diode shown pointing left	B1
	lower right and upper left diodes shown pointing left	B1
7(a)(iii)	arrow indicating current direction in resistor to the right	B1
7(b)(i)	sketch: periodic line showing minimum $V_{OUT} = 0$ and maximum $V_{OUT} = +V_0$	B1
	line showing peak V_{OUT} at $t = 0, 0.5T, 1.0T, 1.5T$ and $2.0T$, with V_{OUT} going to zero half-way in between each peak	B1
	line showing correct modulated sine shape	B1
7(b)(ii)	sketch: sinusoidal curve with troughs sitting on the time axis	B1
	<u>peak</u> power at $t = 0, 0.5T, 1.0T, 1.5T$ and $2.0T$ and zero power half-way in between each peak	B1
7(b)(iii)	same power-time graph with or without rectification, so same V_{rms} or V^2 -time graph is same for both V_{OUT} and V_{IN} , so same V_{rms} or power does not depend on sign of V , so same V_{rms}	B1

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Question	Answer	Marks
8(a)	transition (emits) (one) photon with energy equal to the difference in energy between the two levels	B1
	frequency of radiation corresponds to energy of photon	B1
8(b)(i)	line to the left of the pair in Fig. 8.2, labelled A	B1
	larger gap between line A and the nearest of the pair in Fig. 8.2 than between the lines in the pair	B1
8(b)(ii)	line to the left of both the pair in Fig. 8.2 and line A, labelled B	B1
	larger gap between line B and line A than between line A and the nearest one of the pair in Fig. 8.2	B1
8(c)	$E = hf$	C1
	$E_3 = E_1 + h(f_A + f_B)$	A1

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Question	Answer	Marks
9(a)	difference between mass of nucleus and (total) mass of nucleons	M1
	when infinitely separated	A1
9(b)(i)	neutron	B1
9(b)(ii)	$E = \Delta m c^2$	C1
	$\Delta m = (0.030377 - 0.002388 - 0.009105)u$ (= 0.018884u)	C1
	energy release = $(0.030377 - 0.002388 - 0.009105) \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 = 2.8 \times 10^{-12} \text{ J}$	A1
9(c)(i)	number of atoms per unit time = $(1.4 \times 10^{28}) / (2.8 \times 10^{-12})$ (= $5.0 \times 10^{39} \text{ s}^{-1}$)	C1
	mass of one atom = $4 \times 1.66 \times 10^{-27}$ or $(4 \times 10^{-3}) / (6.02 \times 10^{23})$ (= $6.64 \times 10^{-27} \text{ kg}$)	C1
	mass per unit time = $6.64 \times 10^{-27} \times 5.0 \times 10^{39}$ = $3.3 \times 10^{13} \text{ kg s}^{-1}$	A1
9(c)(ii)	$L = 4\pi\sigma r^2 T^4$	C1
	$1.4 \times 10^{28} = 4\pi \times 5.67 \times 10^{-8} \times (2.3 \times 10^9)^2 \times T^4$	
	$T = 7800 \text{ K}$	A1

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Question	Answer	Marks
10(a)(i)	electrons	B1
10(a)(ii)	electrons are decelerated / stopped on impact with the target	B1
	(kinetic) energy lost by electrons emitted as (X-ray) photons	B1
10(a)(iii)	$eV = hc / \lambda$	C1
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (1.60 \times 10^{-19} \times 5800)$	C1
	$= 2.14 \times 10^{-10} \text{ m}$	A1
10(b)	$I = I_0 \exp(-\mu x)$	C1
	$I_T / I_0 = \exp(-(1.4 \times 2.8))$ $= 0.020$	C1
	% absorbed $= (1.000 - 0.0198) \times 100$ $= 98\%$	A1



Cambridge International AS & A Level

PHYSICS

9702/43

Paper 4 A Level Structured Questions

May/June 2023

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 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

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 descriptors 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.

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>method</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)(i)	force per unit mass	B1
1(a)(ii)	force per unit positive charge	B1
1(a)(iii)	similarity: - inversely proportional to distance (from point) - points of equal potential lie on concentric spheres - zero at infinite distance <i>Any point, 1 mark</i>	B1
	difference: - gravitational potential is (always) negative - electric potential can be positive or negative <i>Any point, 1 mark</i>	B1
1(b)(i)	$g = GM / r^2$	M1
	$E = Q / 4\pi\epsilon_0 r^2$	M1
	algebra showing the elimination of r leading to $M / Q = (1 / 4\pi G\epsilon_0) (g / E)$	A1
1(b)(ii)	$\alpha = 1 / (4\pi \times 6.67 \times 10^{-11} \times 8.85 \times 10^{-12}) = 1.35 \times 10^{20} \text{ (kg}^2 \text{ C}^{-2}\text{)}$ or $\alpha = (8.99 \times 10^9) / (6.67 \times 10^{-11}) = 1.35 \times 10^{20} \text{ (kg}^2 \text{ C}^{-2}\text{)}$	A1
1(c)(i)	$E = \alpha g Q / M$ $= (1.35 \times 10^{20} \times 9.81 \times 4.80 \times 10^5) / (5.98 \times 10^{24})$	C1
	$= 106 \text{ N C}^{-1}$ or 106 V m^{-1}	A1
1(c)(ii)	same (direction)	B1

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Question	Answer	Marks
2(a)	horizontal force on sphere causes centripetal acceleration	B1
	weight of sphere is (now) equal to vertical component of tension or horizontal and vertical components (of force) (now) combine to give greater tension (in spring)	B1
	greater tension in spring so greater extension of spring	B1
2(b)(i)	$r = 10.8 \times \sin 27^\circ = 4.9 \text{ cm}$	A1
2(b)(ii)	$T \cos \theta = mg$ or $T \cos \theta = W$ and $W = mg$	C1
	$T \cos 27^\circ = 0.29 \times 9.81$ leading to $T = 3.2 \text{ N}$	A1
2(b)(iii)	$\Delta T = 3.2 - (0.29 \times 9.81)$	C1
	$k = \Delta T / \Delta x$ $= [3.2 - (0.29 \times 9.81)] / [10.8 - 8.5]$ $= 0.15 \text{ N cm}^{-1}$	A1
2(c)(i)	centripetal acceleration $= (T \sin \theta) / m$ $= (3.2 \times \sin 27^\circ) / 0.29$	C1
	$= 5.0 \text{ m s}^{-2}$	A1

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Question	Answer	Marks
2(c)(ii)	$a = r\omega^2$ and $\omega = 2\pi / T$ or $a = v^2 / r$ and $v = 2\pi r / T$	C1
	$T = 2\pi \times \sqrt{(0.049 / 5.0)}$ $= 0.62 \text{ s}$	A1

Question	Answer	Marks
3(a)	no <u>net</u> thermal energy is transferred (between them)	B1
3(b)(i)	variation (of density with temperature) is linear or each temperature has a unique value of density	B1
3(b)(ii)	- variation (of density with temperature) is not linear - region where the density does not vary with temperature - different temperatures have the same density <i>Any two points, 1 mark each</i>	B2
3(c)(i)	boiling point = 80 °C	A1
3(c)(ii)	$Q = Pt$ and $t = 21 \text{ s}$ (thermal energy supplied = $810 \times 21 = 17000 \text{ J}$)	C1
	$c = Q / m\Delta\theta$	C1
	thermal energy absorbed by beaker = $42 \times 0.84 \times (80 - 25)$ (= 1940 J)	C1
	s.h.c. of liquid = $[(810 \times 21) - (42 \times 0.84 \times (80 - 25))] / [120 \times (80 - 25)]$ = $2.3 \text{ J g}^{-1} \text{ K}^{-1}$	A1
3(d)	sketch: straight diagonal line from 25 °C to 100 °C and then horizontal at 100 °C	B1
	straight diagonal line starting at 25 °C with gradient approximately half that of the original line	B1

Question	Answer	Marks															
4(a)	- particles are in (continuous) random motion - particles have negligible volume (compared with the gas) - negligible forces between particles (except during collisions) (all) collisions (perfectly) elastic - time of collision negligible (in comparison with time between collisions) <i>Any two points, 1 mark each</i>	B2															
4(b)(i)	(general starting equation) $pV = nRT$	C1															
	$T = (2pV / nR)$ where R is the (molar) gas constant	A1															
4(b)(ii)	sketch: straight vertical line XY from $(V, 2p)$ to (V, p)	B1															
	straight horizontal line YZ from (V, p) to $(2V, p)$	B1															
	curve with gradient increasing from Z to X from $(2V, p)$ to $(V, 2p)$	B1															
4(b)(iii)	XY work done on gas correct (= 0)	B1															
	ZX increase in internal energy correct (= 0)	B1															
	YZ work done on gas correct (= $-pV$)	B1															
	XY increase in internal energy such that the increase in internal energy column adds up to zero	B1															
	all three thermal energies transferred such that $\Delta U = q + w$ in each row (completely correct answer: <table><tr><td>change</td><td>ΔU</td><td>Q</td><td>w</td></tr><tr><td>X to Y</td><td>$-U$</td><td>$-U$</td><td>0</td></tr><tr><td>Y to Z</td><td>[$+U$]</td><td>$U + pV$</td><td>$-pV$</td></tr><tr><td>Z to X</td><td>0</td><td>$-W$</td><td>[$+W$]</td></tr></table>)	change	ΔU	Q	w	X to Y	$-U$	$-U$	0	Y to Z	[$+U$]	$U + pV$	$-pV$	Z to X	0	$-W$	[$+W$]
change	ΔU	Q	w														
X to Y	$-U$	$-U$	0														
Y to Z	[$+U$]	$U + pV$	$-pV$														
Z to X	0	$-W$	[$+W$]														

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Question	Answer	Marks
5(a)(i)	correct circuit symbol for a diode shown correctly connected in series with the wires leading into and out of the dotted box	B1
5(a)(ii)	smoothing / V_{OUT} is smoothed	B1
5(b)(i)	frequency = $1 / 0.04$ = 25 Hz	A1
5(b)(ii)	$V = V_0 \exp(-t / RC)$ and $\tau = RC$ or $V = V_0 \exp(-t / \tau)$	C1
	$3.25 = 5.50 \exp(-0.020 / \tau)$ leading to $\tau = 0.038$ s	A1
5(b)(iii)	$\tau = RC$	C1
	capacitance = $0.038 / 14000$ = 2.7×10^{-6} F	A1
5(c)	V_{IN} has constant magnitude in both positive and negative directions	B1
	(so) V_{OUT} is (now) constant / V_{OUT} does not vary with time	B1

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Question	Answer	Marks
6(a)	a region where a force acts on	M1
	a current-carrying conductor or a <u>moving</u> charge or a magnetic material / magnetic pole	A1
6(b)	concentric circles around the wire	B1
	spacing between circles increases with distance from wire	B1
	arrows showing direction of field is clockwise	B1
6(c)(i)	$F = BIL$	C1
	force per unit length = BI $= 2.6 \times 10^{-3} \times 5.0$ $= 0.013 \text{ N m}^{-1}$	A1
6(c)(ii)	to the right	B1
6(c)(iii)	force (per unit length) has the same magnitude due to Newton's 3rd law	B1
	$0.013 = 1.5 \times 10^{-3} \times I$ current = 8.7 A	A1

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Question	Answer	Marks
7(a)	wavelength associated with a <u>moving</u> particle	B1
7(b)(i)	(electron) diffraction	B1
7(b)(ii)	beam spreads out indicating diffraction or light and dark regions indicate an interference pattern	B1
	electron beam is behaving as a wave	B1
7(c)(i)	central blob and concentric rings	B1
	rings closer together (than previously)	B1
7(c)(ii)	(greater p.d. so) electrons to have greater momentum	B1
	greater momentum so decrease in (de Broglie) wavelength	B1
	lower (de Broglie) wavelength (for same grating spacing in crystal) causes: smaller diffraction angle or smaller angle of intensity maxima (for each order) or decrease in fringe spacing in diffraction pattern	B1

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Question	Answer	Marks
8(a)(i)	specific acoustic impedance = $1200 \times 1400 = 1.68 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$	A1
8(a)(ii)	density of air shown in table as 1.29	A1
	speed of sound in tissue shown in table as 1540	A1
8(b)(i)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ $= (1680000 - 440)^2 / (1680000 + 440)^2$	C1
	$= 0.999$	A1
8(b)(ii)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ $= (1680000 - 1680000)^2 / (1680000 + 1680000)^2$ $= 0$	A1
8(c)	without gel, (almost) all of the (incident) ultrasound is reflected (from skin)	B1
	with gel, (almost) all of the (incident) ultrasound is transmitted (into the body)	B1

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Question	Answer	Marks
9(a)	time for activity (of sample) to halve	B1
9(b)	sketch: line with positive gradient starting at (0,0) and extending to $t = 80$ min	B1
	exponential curve, extending from $t = 0$ to $t = 80$ min, with gradient of steadily decreasing magnitude	B1
	line passing through (0,0), (20, $0.5N_0$) and (40, $0.75 N_0$)	B1
9(c)(i)	every (undecayed) nucleus has the same probability of decay	M1
	fewer (undecayed) nuclei remaining (with time), so fewer will decay (in a given time interval)	A1
9(c)(ii)	- sample emits in all directions but detector only captures emissions in one direction - some emissions are absorbed before reaching detector - some emissions are scattered within the sample - simultaneous arrival of multiple particles only registers once - some particles may reach detector but not cause ionisation <i>Any two points, 1 mark each</i>	B2
	measured count rate is less than the activity	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)	$F = L / (4\pi d^2)$	C1
	$= (3.8 \times 10^{31}) / [4\pi \times (1.8 \times 10^{24})^2]$	A1
	$= 9.3 \times 10^{-19} \text{ W m}^{-2}$	
10(c)(i)	galaxy is moving away (from the Earth)	B1
	wavelength (of light from the galaxy) increased by the Doppler effect / due to redshift	B1
10(c)(ii)	$\Delta\lambda / \lambda = v / c$ $v = [(492 - 486) \times 3.00 \times 10^8] / 486$ $(v = 3.7 \times 10^6 \text{ m s}^{-1})$	C1
	$H_0 = v / d$	C1
	$= (3.7 \times 10^6) / (1.8 \times 10^{24})$ $= 2.1 \times 10^{-18} \text{ s}^{-1}$	A1