



Cambridge International AS & A Level

PHYSICS

9702/41

Paper 4 A Level Structured Questions

October/November 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.

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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	<u>'List rule' guidance</u> For questions that require <i>n</i> responses (e.g. State two reasons ...): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked <i>ignore</i> in the mark scheme should not count towards <i>n</i>. • Incorrect responses should not be awarded credit but will still count towards <i>n</i>. • 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 <i>n</i> 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.

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Question	Answer	Marks
1(a)(i)	direction of the force acting on a (test) mass placed at the point	B1
1(a)(ii)	change in height negligible compared with radius (of Earth)	B1
	(so) field lines are (effectively) parallel	B1
1(b)(i)	$Y = GM / R^2$	M1
	G is the gravitational constant	A1
1(b)(ii)	gravitational force is (always) attractive or gravitational force (always) acts towards the centre of the sphere	B1
	force is in opposite direction to displacement or at a point to the right of the centre, force acts to the left or at a point to the left of the centre, force acts to the right	B1
1(b)(iii)	sketch: smooth curve with decreasing positive gradient, starting at $(R, -Y)$ and reaching $3R$ with g still negative or smooth curve with increasing positive gradient, ending at $(-R, Y)$ and reaching $-3R$ with g still positive	B1
	both of the above curves, in correct quadrants	B1
	curve passing through $(\pm 2R, \pm 0.25Y)$ and $(\pm 3R, \pm 0.11Y)$	B1

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Question	Answer	Marks
2(a)	(thermal) energy per unit mass (to change temperature)	B1
	(thermal) energy per unit change in temperature	B1
2(b)(i)	work done = $p\Delta V$ $= (2.0 \times 10^5) \times (0.063 - 0.038) = 5000 \text{ J}$	A1
2(b)(ii)	gas is expanding (against external pressure)	B1
	gas does work / work is done by gas, so (work done on gas is) negative	B1
2(b)(iii)	$\Delta U = q + W$	C1
	$7600 = q + (-5000)$	A1
	$q = 12\,600 \text{ J}$	
2(b)(iv)	specific heat capacity = $q / m\Delta T$ $= 12600 / (0.35 \times 56)$	C1
	$= 640 \text{ J kg}^{-1} \text{ K}^{-1}$	A1
2(c)	same gain in internal energy so same temperature rise	B1
	no change in volume so no work done or no work done so less thermal energy needed (for same change in internal energy)	B1
	less thermal energy needed (for same temperature change) so lower specific heat capacity	B1

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Question	Answer	Marks
3(a)(i)	N : number of molecules (of the gas)	B1
	m : mass of one molecule (of the gas)	B1
	$\langle c^2 \rangle$: mean square speed (of molecules)	B1
3(a)(ii)	$pV = NkT$	M1
	$NkT = \frac{1}{3}Nm\langle c^2 \rangle$ and $E_K = \frac{1}{2}m\langle c^2 \rangle$ leading to $E_K = (3/2)kT$	A1
3(b)	$\frac{1}{2} \times 3.34 \times 10^{-27} \times 9300^2 = (3/2) \times 1.38 \times 10^{-23} \times T$	C1
	$T = 6980 \text{ K}$	A1
3(c)(i)	$L = F \times 4\pi d^2$	C1
	$L = 2.52 \times 10^{-8} \times 4\pi \times (4.16 \times 10^{16})^2$	A1
	$= 5.48 \times 10^{26} \text{ W}$	
3(c)(ii)	$L = 4\pi\sigma r^2 T^4$	C1
	$5.48 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times r^2 \times 6980^4$	
	$r = 5.69 \times 10^8 \text{ m}$	A1
3(d)	(very high pressure so) molecules are (very) close together (<i>not just 'nearer'</i>)	B1
	forces between molecules are not negligible or volume of molecules not negligible compared with gas volume	B1

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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)	$\omega = 2\pi / T$	C1
	$\omega = 2\pi / 3.0$ $= 2.1 \text{ rad s}^{-1}$	A1
4(b)(ii)	$E = \frac{1}{2}m\omega^2x_0^2$	C1
	$= \frac{1}{2} \times 0.81 \times 2.1^2 \times 0.036^2$ $= 2.3 \times 10^{-3} \text{ J}$	A1
4(c)	sketch: line starting at (0, 0.036) and not reaching $x = \pm 0.036 \text{ m}$ at any other time	B1
	smooth curve, with no sudden changes in gradient, showing continuously decreasing magnitude of x from maximum displacement at $t = 0$ to final displacement of zero where the gradient is also zero	B1
	displacement reaches final value of zero between $t = 0.75 \text{ s}$ and $t = 3.0 \text{ s}$ at the latest	B1

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Question	Answer	Marks
5(a)	work done per unit charge	B1
	work (done on charge) moving positive charge from infinity (to the point)	B1
5(b)	<i>Any three points from:</i> <i>Up to 2 points from:</i> • radius of sphere X is 2.0 m • radius of sphere Y is 4.0 m • radius of Y is double the radius of X <i>Up to 2 points from:</i> • charge on X is negative • charge on Y is positive • spheres carry opposite charges <i>Up to 1 point from:</i> • magnitudes of charges on the spheres are equal	B3
5(c)	particle is attracted to X or repelled from Y or resultant force on particle is towards X / away from Y / to the left	B1
	particle accelerates towards X / away from Y / to the left	B1
	(magnitude of) acceleration of particle increases	B1

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Question	Answer	Marks
6(a)	• force per unit length • force per unit current • length / current perpendicular to field 1 mark for any two points, 2 marks for all three points	B2
6(b)(i)	into the page	B1
6(b)(ii)	$F = Bqv$	C1
	$= 4.8 \times 10^{-3} \times 1.6 \times 10^{-19} \times 1.7 \times 10^7 = 1.3 \times 10^{-14} \text{ N}$	A1
6(b)(iii)	arrow at point X pointing down the page	B1
6(b)(iv)	$F = mv^2 / r$	C1
	$1.3 \times 10^{-14} = (9.11 \times 10^{-31}) \times (1.7 \times 10^7)^2 / r$	C1
	$(r = 0.020 \text{ m})$ $d = 2r$ $d = 0.040 \text{ m}$	A1
6(c)	path shows upwards deflection such that the curvature is always anticlockwise within the field	B1
	circular path with larger radius	B1
	line enters field at X and leaves field at distance $2d$ vertically from X	B1

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Question	Answer	Marks
7(a)(i)	$P = I_0^2 R$	A1
7(a)(ii)	$P = 4I_0^2 R$	A1
7(b)	sketch: square wave of period T , with P always non-zero	B1
	horizontal lines, from 0 to $0.5T$ and from $1.0T$ to $1.5T$, all at the same level that the scale indicates to be $I_0^2 R$	B1
	horizontal lines, from $0.5T$ to $1.0T$ and from $1.5T$ to $2.0T$, at a level that is four times higher than the lower lines	B1
7(c)(i)	$\langle P \rangle = (5/2)I_0^2 R$	A1
7(c)(ii)	$\langle P \rangle = I_{\text{r.m.s.}}^2 R$	C1
	$I_{\text{r.m.s.}}^2 R = (5/2)I_0^2 R$	A1
	$I_{\text{r.m.s.}} = \sqrt{(5/2)} I_0$	

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Question	Answer	Marks
8(a)(i)	$p = E / c$	M1
	$E = hc / \lambda$ and completion of algebra leading to $p = h / \lambda$	A1
8(a)(ii)	wavelength = $(6.63 \times 10^{-34}) / (9.5 \times 10^{-28}) = 700 \times 10^{-9} \text{ m}$ so red	B1
8(b)(i)	power = intensity $\times$ area	C1
	number per unit time = $(160 \times 2.5 \times 10^{-6}) / (9.5 \times 10^{-28} \times 3.00 \times 10^8) = 1.4 \times 10^{15} \text{ s}^{-1}$	A1
8(b)(ii)	pressure = force / area	C1
	force = rate of change of momentum $= 2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}$	C1
	pressure = $(2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}) / (2.5 \times 10^{-6})$ $= 1.1 \times 10^{-6} \text{ Pa}$	A1
8(c)	photons have greater momentum or fewer photons per unit time	B1
	greater photon momentum but smaller number of photons (per unit time) so pressure is the same	B1

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Question	Answer	Marks
9(a)	(two small) nuclei join together	M1
	to form one larger nucleus	A1
9(b)	line with a peak at $A \approx 56$	B1
	line with steep initial positive gradient on the left of peak and shallower negative gradient at all points to the right of peak and line does not return to 0 binding energy	B1
9(c)(i)	X shown at value of A to the right of the peak	B1
9(c)(ii)	Y shown at value of A close to 1	B1
9(d)	energy from 1 nucleus = $(1.77 \times 10^{13}) / (6.02 \times 10^{23})$ $(= 2.94 \times 10^{-11} \text{ J})$	C1
	binding energy of Z = $[(1.25 + 1.81) \times 10^{-10}] - 2.94 \times 10^{-11}$ $(= 2.77 \times 10^{-10} \text{ J})$	C1
	nucleon number of Z = $93 + 139 + 2 - 1$ $(= 233)$	C1
	binding energy per nucleon = $(2.77 \times 10^{-10}) / (233 \times 1.60 \times 10^{-13})$ $= 7.43 \text{ MeV}$	A1

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Question	Answer	Marks
10(a)	ultrasound production: vibrating quartz crystal	B1
	X-ray production: electrons hitting metal target	B1
	ultrasound detected wave: reflected	B1
	X-ray detected wave: transmitted	B1
10(b)(i)	$I = I_0 \exp(-\mu x)$	C1
	$\ln(0.72) = -6.2\mu$	A1
	$\mu = 0.053 \text{ cm}^{-1}$	
10(b)(ii)	$I / I_0 = \exp(-9.3 \times 0.053)$ (= 0.61)	C1
	percentage attenuated = $100 \times (1.00 - 0.61)$ = 39%	A1



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 For questions that require ***n*** responses (e.g. State **two** reasons ...):
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 - 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***.
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 - 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.
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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.
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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.

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Question	Answer	Marks
1(a)	angle (subtended at centre of circle) when arc length = radius	B1
1(b)	$\omega = 2\pi / T$	C1
	$= 2\pi / (1.0 \times 60 \times 60)$	A1
	$= 1.7 \times 10^{-3} \text{ rad s}^{-1}$	
1(c)(i)	angle $= 1.7 \times 10^{-3} \times 1400$ $= 2.4 \text{ rad}$	A1
1(c)(ii)	$L = \text{arc length} / \text{angle}$ $= 0.44 / 2.4$ or $L = 0.44 \times (3600 / 1400) / 2\pi$	C1
	$L = 0.18 \text{ m}$	A1
1(c)(iii)	$a = r\omega^2$	C1
	$= 0.18 \times (1.745 \times 10^{-3})^2$	A1
	$= 5.5 \times 10^{-7} \text{ m s}^{-2}$	
1(d)	centripetal acceleration is negligible compared with acceleration of free fall or numerical comparison establishing answer to (c)(iii) $\ll 9.81$	B1
	resultant force is negligible compared with weight (of modelling clay) (so variation is negligible) or force exerted by minute hand (approximately) equal (and opposite) to weight of modelling clay	B1

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Question	Answer	Marks
2(a)(i)	work done per unit mass	B1
	work (done) moving mass from infinity (to the point)	B1
2(a)(ii)	$\phi = -GM / r$ $= - (6.67 \times 10^{-11} \times 7.3 \times 10^{22}) / (1.7 \times 10^6)$	C1
	$= - 2.9 \times 10^6 \text{ J kg}^{-1}$	A1
2(b)(i)	$E_P = m\phi$	B1
2(b)(ii)	$\frac{1}{2}mv^2 + m\phi = 0$	M1
	correct algebra leading to $v = \sqrt{-2\phi}$	A1
2(c)	speed $= \sqrt{2 \times 2.9 \times 10^6}$ $= 2400 \text{ m s}^{-1}$	A1
2(d)	$\frac{1}{2}m\langle c^2 \rangle = (3/2)kT$	C1
	$3.34 \times 10^{-27} \times \langle c^2 \rangle = 3 \times 1.38 \times 10^{-23} \times 400$	C1
	$c_{\text{r.m.s.}} = 2200 \text{ m s}^{-1}$	A1
2(e)	r.m.s. speed is an average so many molecules have speeds greater than the escape speed or there is a distribution of molecular speeds (around the r.m.s. value) so many molecules have speeds greater than the escape speed	B1

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Question	Answer	Marks
3(a)	sum of potential energy and kinetic energy (of particles)	B1
	(total) energy of random motion of particles	B1
3(b)(i)	no thermal energy <u>transferred</u>	B1
	work is done on the spring (increasing the potential energy of particles)	M1
	so internal energy increases	A1
3(b)(ii)	thermal energy transferred to water	B1
	work is done by water (expanding against atmosphere as it vaporises)	B1
	more thermal energy transferred than work done so internal energy increases	B1

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Question	Answer	Marks
4(a)(i)	$\text{amplitude} = \frac{1}{2} \times 7.2 \times 10^{-15}$ $= 3.6 \times 10^{-15} \text{ m}$	A1
4(a)(ii)	$\omega = 2\pi / (0.20 \times 10^{-6})$ $= 3.1 \times 10^7 \text{ rad s}^{-1}$	A1
4(a)(iii)	$v_0 = \omega x_0$	C1
	$v_0 = 3.1 \times 10^7 \times 3.6 \times 10^{-15} = 1.1 \times 10^{-7} \text{ m s}^{-1}$	A1
4(b)(i)	$I_0 = nAv_0e$ $= 8.5 \times 10^{28} \times 4.3 \times 10^{-4} \times 1.1 \times 10^{-7} \times 1.60 \times 10^{-19}$	C1
	$= 0.64 \text{ A}$	A1
4(b)(ii)	sketch: two cycles of sinusoidal curve of amplitude I_0 and period $0.20 \mu\text{s}$	B1
	correct phase, with $I = +I_0$ at $t = 0$	B1
4(b)(iii)	equation of form $I = I_0 \cos \omega t$	M1
	value of I_0 used matches answer to (b)(i) and value of ω used matches answer to (a)(ii)	A1
	[if (a)(ii) and (b)(i) correct then $I = 0.64 \cos (3.1 \times 10^7 t)$]	
4(b)(iv)	$I_{\text{r.m.s.}} = I_0 / \sqrt{2}$ $= 0.64 / \sqrt{2}$ $= 0.45 \text{ A}$	A1

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Question	Answer	Marks
5(a)	(electric) force is (directly) proportional to product of charges	B1
	(electric) force (between point charges) is inversely proportional to the square of their separation	B1
5(b)	$F = Q^2 / 4\pi\epsilon_0 X^2$	C1
	$6.3 \times 10^{-17} = Q^2 / [4\pi \times 8.85 \times 10^{-12} \times (3.8 \times 10^{-6})^2]$	
	charge = 3.2×10^{-19} C	A1
5(c)(i)	negative	B1
5(c)(ii)	four straight lines perpendicular to the plates, starting on one plate and finishing on the other	B1
	lines equally spaced	B1
	arrows indicating direction downwards	B1
5(c)(iii)	$E = V / d$	C1
	$mg = EQ$	C1
	mass = $(1200 \times 3.2 \times 10^{-19}) / (9.81 \times 0.052)$ $= 7.5 \times 10^{-16}$ kg	A1

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Question	Answer	Marks
6(a)(i)	energy stored = area under graph	C1
	$= \frac{1}{2} \times 450 \times 10^{-6} \times 8.0 = 1.8 \times 10^{-3} \text{ J}$ or 1.8 mJ	A1
6(a)(ii)	$C = Q / V$ or $E = \frac{1}{2} CV^2$	C1
	$C = (450 \times 10^{-6}) / 8.0$ or $(2 \times 1.8 \times 10^{-3}) / 8.0^2$ $= 5.6 \times 10^{-5} \text{ F}$	A1
6(b)(i)	$V = V_0 \exp(-t / RC)$ and $\tau = RC$	C1
	$V = V_0 \exp(-t / \tau)$ $V_0 = 8.0 \text{ V}$, and at one time constant, $t = \tau$ $V / 8.0 = \exp(-\tau / \tau)$, so $\ln(V / 8.0) = -1.0$ or $-\ln(V / 8.0) = 1.0$	A1
6(b)(ii)	[t read from graph at $-\ln(V / 8.0) = 1.0$]: $\tau = 3.2 \text{ s}$	A1
6(b)(iii)	$\tau = RC$	C1
	$R = 3.2 / (5.6 \times 10^{-5})$ $= 5.7 \times 10^4 \Omega$	A1

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Question	Answer	Marks
7(a)(i)	$V_H = BI / ntq$ $= (4.0 \times 10^{-6} \times 5.4) / (1.5 \times 10^{16} \times 1.8 \times 10^{-3} \times 1.60 \times 10^{-19}) = 5.0 \text{ V}$	A1
7(a)(ii)	sketch: straight diagonal line from (0, 0) to $t = 0.020 \text{ s}$ and straight diagonal line between two non-zero V_H values of same sign from $t = 0.040$ to 0.050 s	B1
	horizontal straight line at $V_H = 5.0 \text{ V}$ from $t = 0.020$ to 0.040 s	B1
	horizontal straight line at $V_H = 2.5 \text{ V}$ from $t = 0.050$ to 0.080 s	B1
7(b)(i)	e.m.f. = rate of change of (magnetic) flux (linkage)	C1
	$E = NA \Delta B / \Delta t$ or $E = NA \times \text{gradient (at } t = 0.010 \text{ s)}$	C1
	$E = 3000 \times 3.4 \times 10^{-4} \times (4.0 \times 10^{-6}) / (0.020) = 2.0 \times 10^{-4} \text{ V}$	A1
7(b)(ii)	sketch: line showing non-zero E from $t = 0$ to $t = 0.020 \text{ s}$ and from $t = 0.040 \text{ s}$ to $t = 0.050 \text{ s}$, and $E = 0$ at all other times	B1
	‘top hats’ showing constant non-zero E from $t = 0$ to $t = 0.020 \text{ s}$ and from $t = 0.040 \text{ s}$ to $t = 0.050 \text{ s}$	B1
	magnitude of E shown as $2.0 \times 10^{-4} \text{ V}$ in both non-zero sections	B1
	sign of E in the $t = 0$ to $t = 0.020 \text{ s}$ region opposite to the sign of E in the $t = 0.040 \text{ s}$ to $t = 0.050 \text{ s}$ region	B1

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Question	Answer	Marks
8(a)	packet / quantum of <u>energy</u>	M1
	of electromagnetic radiation	A1
8(b)(i)	photoelectric effect	B1
8(b)(ii)	- electron needs a minimum energy to escape or - electron emitted if energy in packet is enough - energy must be absorbed in packets that are related to frequency - intensity relates to number of packets (not to energy in packet) - electron absorbs only a single whole packet <i>Any three points, 1 mark each</i>	B3
8(c)(i)	Planck constant	B1
8(c)(ii)	– work function (energy)	B1

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Question	Answer	Marks
9(a)(i)	material introduced into the body and (position in body) can be detected or absorbed by the tissue (being studied)	B1
9(a)(ii)	$X = \beta^+ \text{ or } e^+ \text{ and } P = 1$	B1
	$Q = 0 \quad \text{and } R = 18$	B1
9(b)(i)	positrons (emitted in the decay) and electrons annihilate	B1
	mass of particles becomes energy of gamma photons	B1
9(b)(ii)	arrival times of photons are processed	B1
	image built up of tracer concentration in the tissue	B1
9(c)(i)	$A = \lambda N \text{ and } \lambda = \ln 2 / T$	C1
	$N = n \times N_A$	C1
	2 photons produced from each decay, so $R_0 = 2 \times \lambda \times n \times N_A$	A1
	$R_0 = (2 \ln 2) n N_A / T$ (allow 0.693 for $\ln 2$)	
9(c)(ii)	sketch: exponential decay curve from $t = 0$ to $t = 2T$, starting at $(0, R_0)$ and with a negative gradient of continuously decreasing magnitude	B1
	line with negative gradient passing through $(T, R_0/2)$ and $(2T, R_0/4)$	B1

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Question	Answer	Marks
10(a)	temperature inversely proportional to wavelength	M1
	temperature is thermodynamic temperature of surface, and wavelength is the wavelength at which maximum emission rate occurs	A1
10(b)(i)	(astronomical) object of known luminosity	B1
10(b)(ii)	star / galaxy is moving away from the student	B1
10(b)(iii)	one tick placed in correct column in each row: wavelength: too high	B1
	surface temperature: too low	B1
	distance: unchanged	B1
	radius: too high	B1



Cambridge International AS & A Level

PHYSICS

9702/43

Paper 4 A Level Structured Questions

October/November 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.

Due to a series-specific issue during the live exam series, all candidates were awarded full marks for questions 1 and 10.

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 October/November 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level 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	<u>'List rule' guidance</u> For questions that require <i>n</i> responses (e.g. State two reasons ...): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked <i>ignore</i> in the mark scheme should not count towards <i>n</i>. • Incorrect responses should not be awarded credit but will still count towards <i>n</i>. • 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 <i>n</i> 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.

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Question	Answer	Marks
1(a)(i)	direction of the force acting on a (test) mass placed at the point	B1
1(a)(ii)	change in height negligible compared with radius (of Earth)	B1
	(so) field lines are (effectively) parallel	B1
1(b)(i)	$Y = GM / R^2$	M1
	G is the gravitational constant	A1
1(b)(ii)	gravitational force is (always) attractive or gravitational force (always) acts towards the centre of the sphere	B1
	force is in opposite direction to displacement or at a point to the right of the centre, force acts to the left or at a point to the left of the centre, force acts to the right	B1
1(b)(iii)	sketch: smooth curve with decreasing positive gradient, starting at $(R, -Y)$ and reaching $3R$ with g still negative or smooth curve with increasing positive gradient, ending at $(-R, Y)$ and reaching $-3R$ with g still positive	B1
	both of the above curves, in correct quadrants	B1
	curve passing through $(\pm 2R, \pm 0.25Y)$ and $(\pm 3R, \pm 0.11Y)$	B1

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Question	Answer	Marks
2(a)	(thermal) energy per unit mass (to change temperature)	B1
	(thermal) energy per unit change in temperature	B1
2(b)(i)	work done = $p\Delta V$ $= (2.0 \times 10^5) \times (0.063 - 0.038) = 5000 \text{ J}$	A1
2(b)(ii)	gas is expanding (against external pressure)	B1
	gas does work / work is done by gas, so (work done on gas is) negative	B1
2(b)(iii)	$\Delta U = q + W$	C1
	$7600 = q + (-5000)$	A1
	$q = 12\,600 \text{ J}$	
2(b)(iv)	specific heat capacity = $q / m\Delta T$ $= 12600 / (0.35 \times 56)$	C1
	$= 640 \text{ J kg}^{-1} \text{ K}^{-1}$	A1
2(c)	same gain in internal energy so same temperature rise	B1
	no change in volume so no work done or no work done so less thermal energy needed (for same change in internal energy)	B1
	less thermal energy needed (for same temperature change) so lower specific heat capacity	B1

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Question	Answer	Marks
3(a)(i)	N : number of molecules (of the gas)	B1
	m : mass of one molecule (of the gas)	B1
	$\langle c^2 \rangle$: mean square speed (of molecules)	B1
3(a)(ii)	$pV = NkT$	M1
	$NkT = \frac{1}{3}Nm\langle c^2 \rangle$ and $E_K = \frac{1}{2}m\langle c^2 \rangle$ leading to $E_K = (3/2) kT$	A1
3(b)	$\frac{1}{2} \times 3.34 \times 10^{-27} \times 9300^2 = (3/2) \times 1.38 \times 10^{-23} \times T$	C1
	$T = 6980 \text{ K}$	A1
3(c)(i)	$L = F \times 4\pi d^2$	C1
	$L = 2.52 \times 10^{-8} \times 4\pi \times (4.16 \times 10^{16})^2$	A1
	$= 5.48 \times 10^{26} \text{ W}$	
3(c)(ii)	$L = 4\pi\sigma r^2 T^4$	C1
	$5.48 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times r^2 \times 6980^4$	
	$r = 5.69 \times 10^8 \text{ m}$	A1
3(d)	(very high pressure so) molecules are (very) close together (<i>not just 'nearer'</i>)	B1
	forces between molecules are not negligible or volume of molecules not negligible compared with gas volume	B1

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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)	$\omega = 2\pi / T$	C1
	$\omega = 2\pi / 3.0$ $= 2.1 \text{ rad s}^{-1}$	A1
4(b)(ii)	$E = \frac{1}{2}m\omega^2x_0^2$	C1
	$= \frac{1}{2} \times 0.81 \times 2.1^2 \times 0.036^2$ $= 2.3 \times 10^{-3} \text{ J}$	A1
4(c)	sketch: line starting at (0, 0.036) and not reaching $x = \pm 0.036 \text{ m}$ at any other time	B1
	smooth curve, with no sudden changes in gradient, showing continuously decreasing magnitude of x from maximum displacement at $t = 0$ to final displacement of zero where the gradient is also zero	B1
	displacement reaches final value of zero between $t = 0.75 \text{ s}$ and $t = 3.0 \text{ s}$ at the latest	B1

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Question	Answer	Marks
5(a)	work done per unit charge	B1
	work (done on charge) moving positive charge from infinity (to the point)	B1
5(b)	<i>Any three points from:</i> <i>Up to 2 points from:</i> • radius of sphere X is 2.0 m • radius of sphere Y is 4.0 m • radius of Y is double the radius of X <i>Up to 2 points from:</i> • charge on X is negative • charge on Y is positive • spheres carry opposite charges <i>Up to 1 point from:</i> • magnitudes of charges on the spheres are equal	B3
5(c)	particle is attracted to X or repelled from Y or resultant force on particle is towards X / away from Y / to the left	B1
	particle accelerates towards X / away from Y / to the left	B1
	(magnitude of) acceleration of particle increases	B1

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Question	Answer	Marks
6(a)	• force per unit length • force per unit current • length / current perpendicular to field 1 mark for any two points, 2 marks for all three points	B2
6(b)(i)	into the page	B1
6(b)(ii)	$F = Bqv$	C1
	$= 4.8 \times 10^{-3} \times 1.6 \times 10^{-19} \times 1.7 \times 10^7 = 1.3 \times 10^{-14} \text{ N}$	A1
6(b)(iii)	arrow at point X pointing down the page	B1
6(b)(iv)	$F = mv^2 / r$	C1
	$1.3 \times 10^{-14} = (9.11 \times 10^{-31}) \times (1.7 \times 10^7)^2 / r$	C1
	$(r = 0.020 \text{ m})$ $d = 2r$ $d = 0.040 \text{ m}$	A1
6(c)	path shows upwards deflection such that the curvature is always anticlockwise within the field	B1
	circular path with larger radius	B1
	line enters field at X and leaves field at distance $2d$ vertically from X	B1

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Question	Answer	Marks
7(a)(i)	$P = I_0^2 R$	A1
7(a)(ii)	$P = 4I_0^2 R$	A1
7(b)	sketch: square wave of period T , with P always non-zero	B1
	horizontal lines, from 0 to $0.5T$ and from $1.0T$ to $1.5T$, all at the same level that the scale indicates to be $I_0^2 R$	B1
	horizontal lines, from $0.5T$ to $1.0T$ and from $1.5T$ to $2.0T$, at a level that is four times higher than the lower lines	B1
7(c)(i)	$\langle P \rangle = (5/2)I_0^2 R$	A1
7(c)(ii)	$\langle P \rangle = I_{\text{r.m.s.}}^2 R$	C1
	$I_{\text{r.m.s.}}^2 R = (5/2)I_0^2 R$	A1
	$I_{\text{r.m.s.}} = \sqrt{(5/2)} I_0$	

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Question	Answer	Marks
8(a)(i)	$p = E / c$	M1
	$E = hc / \lambda$ and completion of algebra leading to $p = h / \lambda$	A1
8(a)(ii)	wavelength = $(6.63 \times 10^{-34}) / (9.5 \times 10^{-28}) = 700 \times 10^{-9} \text{ m}$ so red	B1
8(b)(i)	power = intensity $\times$ area	C1
	number per unit time = $(160 \times 2.5 \times 10^{-6}) / (9.5 \times 10^{-28} \times 3.00 \times 10^8) = 1.4 \times 10^{15} \text{ s}^{-1}$	A1
8(b)(ii)	pressure = force / area	C1
	force = rate of change of momentum $= 2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}$	C1
	pressure = $(2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}) / (2.5 \times 10^{-6})$ $= 1.1 \times 10^{-6} \text{ Pa}$	A1
8(c)	photons have greater momentum or fewer photons per unit time	B1
	greater photon momentum but smaller number of photons (per unit time) so pressure is the same	B1

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Question	Answer	Marks
9(a)	(two small) nuclei join together	M1
	to form one larger nucleus	A1
9(b)	line with a peak at $A \approx 56$	B1
	line with steep initial positive gradient on the left of peak and shallower negative gradient at all points to the right of peak and line does not return to 0 binding energy	B1
9(c)(i)	X shown at value of A to the right of the peak	B1
9(c)(ii)	Y shown at value of A close to 1	B1
9(d)	energy from 1 nucleus = $(1.77 \times 10^{13}) / (6.02 \times 10^{23})$ $(= 2.94 \times 10^{-11} \text{ J})$	C1
	binding energy of Z = $[(1.25 + 1.81) \times 10^{-10}] - 2.94 \times 10^{-11}$ $(= 2.77 \times 10^{-10} \text{ J})$	C1
	nucleon number of Z = $93 + 139 + 2 - 1$ $(= 233)$	C1
	binding energy per nucleon = $(2.77 \times 10^{-10}) / (233 \times 1.60 \times 10^{-13})$ $= 7.43 \text{ MeV}$	A1

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Question	Answer	Marks
10(a)	ultrasound production: vibrating quartz crystal	B1
	X-ray production: electrons hitting metal target	B1
	ultrasound detected wave: reflected	B1
	X-ray detected wave: transmitted	B1
10(b)(i)	$I = I_0 \exp(-\mu x)$	C1
	$\ln(0.72) = -6.2\mu$	A1
	$\mu = 0.053 \text{ cm}^{-1}$	
10(b)(ii)	$I / I_0 = \exp(-9.3 \times 0.053)$ (= 0.61)	C1
	percentage attenuated = $100 \times (1.00 - 0.61)$ = 39%	A1