Cambridge International AS & A Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **February/March 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.

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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.

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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 ***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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme. State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

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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)	work done per unit mass	**B1**
	work (done on mass) moving mass from infinity (to the point)	**B1**
1(b)(i)	-3.55×10^7 J kg^{-1}	**B1**
1(b)(ii)	$\phi = -\frac{GM}{r}$ $M = -\frac{-3.55\times10^7 \times 4800000}{6.67\times10^{-11}}$ $= 2.55 \times 10^{24}$ kg	**B1**
1(b)(iii)	$g = \frac{GM}{r^2}$ **or** $g = -\frac{\phi}{r}$	**C1**
	$= \frac{6.67\times10^{-11}\times2.55\times10^{24}}{4800000^2}$ **or** $= \frac{3.55\times10^7}{4800000}$ $= 7.4$ N kg^{-1}	**A1**
1(b)(iv)	r in range 2.60×10^7 to 2.65×10^7 m	**C1**
	$\frac{mv^2}{r} = \frac{GMm}{r^2}$ **and** $v = \frac{2\pi r}{T}$ **or** $mr\omega^2 = \frac{GMm}{r^2}$ **and** $\omega = \frac{2\pi}{T}$	**C1**
	$T^2 = \frac{4\pi^2 r^3}{GM} = \frac{4\pi^2 \times (2.65\times10^7)^3}{6.67\times10^{-11}\times2.55\times10^{24}} = 4.20 \times 10^9$	**C1**
	$T = 64\,800$ s $= 18$ hours	**A1**

Question	Answer	Marks
1(c)	similarity – any one point from • inversely proportional to distance (from point) • points of equal potential lie on concentric spheres • zero at infinite distance	**B1**
	difference – any one point from • gravitational potential is (always) negative • electric potential can be positive or negative	**B1**

Question	Answer	Marks
2(a)	gas for which $pV \propto T$	**M1**
	where T is thermodynamic temperature	**A1**
2(b)(i)	evidence of two temperature conversions between °C and K	**B1**
	two calculations shown, one for each state e.g. $\frac{1.10 \times 10^5 \times 540 \times 10^{-6}}{(273+27)} = 0.198$ **and** $\frac{6.70 \times 10^6 \times 30 \times 10^{-6}}{(273+742)} = 0.198$	**A1**
2(b)(ii)	work is done on the gas	**M1**
	internal energy increases (so temperature increases)	**A1**

Question	Answer	Marks
2(b)(iii)	$pV = NkT$ e.g. $N = \dfrac{1.10\times10^{5}\times540\times10^{-6}}{1.38\times10^{-23}\times300}$ $= 1.435 \times 10^{22}$ $\Delta E_{k} = (3/2)\,k\Delta TN$	**C1**
	$= (3/2) \times 1.38 \times 10^{23} \times (742 - 27) \times \dfrac{1.10\times10^{5}\times540\times10^{-6}}{1.38\times10^{-23}\times300}$	**C1**
	= 212 J	**A1**
2(c)	$E = mc\Delta\theta$ **and** $E = mL$	**C1**
	$\Delta\theta$ = (27 + 196) or 223	**C1**
	$E = 0.0240 \times 1.04 \times (27 + 196) + 0.0240 \times 199$ = 10.3 kJ	**A1**

Question	Answer	Marks
3(a)	P: total energy Q: potential energy R: kinetic energy	**B2**
3(b)	$E = ½m\omega^2{x_0}^2$ **or** $E = ½m{v_0}^2$ **and** $v_0 = \omega x_0$	**C1**
	$6.4 \times 10^{-3} = ½ \times 0.130 \times \omega^2 \times 0.015^2$ ($\omega^2 = 438$) ($\omega = 20.9$)	**C1**
	$T = 2\pi / \omega$	**C1**
	$= 2\pi / 20.9$ $= 0.30$ s	**A1**
3(c)(i)	resistive forces	**B1**
3(c)(ii)	0.92^6	**C1**
	decrease in energy $= 6.4 - (6.4 \times 0.92^6)$ $= 2.5$ mJ	**A1**
3(c)(iii)	light damping because the amplitude of oscillations gradually reduces **or** light damping because the system still oscillates	**B1**

Question	Answer	Marks
4(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**
4(b)(i)	arrows showing tension upwards in direction of string, electric force horizontally to the right and weight vertically downwards and all three labelled	**B1**
4(b)(ii)	$F_E = \dfrac{96 \times 10^{-9} \times 64 \times 10^{-9}}{4 \times \pi \times 8.85 \times 10^{-12} \times 0.080^2}$ $(= 8.63 \times 10^{-3}\text{ N})$	**C1**
	either angle to vertical $= \sin^{-1} 0.080 / 1.2$ $(= 3.82°)$	**C1**
	weight $= F_E / \tan 3.82 = 8.63 \times 10^{-3} / \tan 3.82$ $(= 0.129\text{ N})$	**C1**
	mass = 0.129 / 9.81 = 0.013 kg	**A1**
	or $T \sin \theta = mg$ **and** $T \cos \theta = F_E$ **or** $\tan \theta = mg / F_E$	**(C1)**
	$\tan \theta = 1.2 / 0.080$	**(C1)**
	$m = (1.2 \times 8.63 \times 10^{-3}) / (0.080 \times 9.81)$ = 0.013 kg	**(A1)**

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Question	Answer	Marks
4(b)(iii)	$E_p = \frac{Q_1Q_2}{4\pi\varepsilon_o r} = \frac{96\times10^{-9}\times64\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.080}$ $= 6.9 \times 10^{-4}$ J	**A1**
4(c)(i)	towards the top of the page / towards plate P	**B1**
4(c)(ii)	$F = QE$ **and** $E = V / d$	**C1**
	$F = 1.6 \times 10^{-19} \times 250 / 0.018$ $= 2.2 \times 10^{-15}$ N	**A1**
4(c)(iii)	**either** the force is not (always) perpendicular to the velocity **or** the force is always in the same direction	**B1**

Question	Answer	Marks
5(a)	from graph ln Q = 2.9 (so Q = 18.2 μC)	B1
	$C = Q / V$	C1
	$= 18.2 / 12 = 1.5\ \mu F$	A1
5(b)	gradient = –0.25	C1
	gradient = –1 / RC	C1
	$R = 1 / (0.25 \times 1.5 \times 10^{-6})$ $= 2.7 \times 10^{6}\ \Omega$	A1
	or $\dfrac{Q}{Q_0} = e^{-t/CR}$ **or** $\ln Q - \ln Q_0 = \dfrac{-t}{CR}$	(C1)
	e.g. $\dfrac{4.95}{18.2} = e^{-5.2/(1.5 \times 10^{-6} R)}$ **or** $1.6 - 2.9 = 5.2 / (1.5 \times 10^{-6} R)$	(C1)
	$R = 2.7 \times 10^{6}\ \Omega$	(A1)

Question	Answer	Marks
5(c)	$W = ½ QV$	C1
	$= ½ \times 18.2 \times 10^{-6} \times 12$ $= 1.1 \times 10^{-4}$ J	A1
	or $W = ½ CV^2$	(C1)
	$= ½ \times 1.5 \times 10^{-6} \times 12^2$ $= 1.1 \times 10^{-4}$ J	(A1)
	or $W = ½ Q^2 / C$	(C1)
	$= ½ \times (18.2 \times 10^{-6})^2 / 1.5 \times 10^{-6}$ $= 1.1 \times 10^{-4}$ J	(A1)
5(d)	straight line with different negative gradient starting from (0, 2.9)	M1
	straight line between $t = 0$ and at least $t = 5.0$ s with twice the gradient of the original line	A1

Question	Answer	Marks
6(a)	it is zero when (plane of) probe is parallel to the (magnetic) field (lines)	B1
	it is maximum when (plane of) probe is perpendicular to (magnetic) field (lines)	B1
6(b)(i)	number density of charge carriers	B1
6(b)(ii)	smaller value of *n* so greater Hall voltage / V_H	B1
6(c)	(36 mV corresponds to) 48 mT	C1
	use of 1.4 s or (8.6 – 7.2) s	C1
	$E = \Delta BAN / \Delta t$	C1
	$= \dfrac{48 \times 10^{-3} \times 0.018^2 \times \pi \times 780}{1.4}$ = 0.027 V	A1

Question	Answer	Marks
7(a)	photon absorbed (by electron) and electron excited	B1
	photon energy equal to difference in (energy of two) energy levels	B1
	photon energy relates to a single wavelength / single frequency	B1
	electron de-excites and emits photon in any direction	B1
7(b)	$\frac{hc}{\lambda} = \Delta E$	C1
	uses 658 nm	C1
	$\frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{658 \times 10^{-9}} = -E_1 - (-3.40 \times 1.60 \times 10^{-19})$ $E_1 = -2.42 \times 10^{-19}$ J	A1

Question	Answer	Marks
8(a)	234, 92 for the uranium nucleus	**B1**
	4, 2 for the alpha particle	**B1**
8(b)(i)	$N_0 = 0.874 / (238 \times 1.66 \times 10^{-27})$ $= 2.21 \times 10^{24}$	**A1**
8(b)(ii)	$A = \lambda N$	**C1**
	$= \dfrac{\ln 2}{87.7 \times 365 \times 24 \times 3600} \times 2.21 \times 10^{24}$ $= 5.54 \times 10^{14}$ Bq	**A1**
8(b)(iii)	power $= 5.54 \times 10^{14} \times 5.59 \times 10^{6} \times 1.60 \times 10^{-19}$	**C1**
	$= 496$ W	**A1**
8(b)(iv)	$65.3 = 100e^{-\frac{\ln 2}{87.7}t}$	**C1**
	$\ln 0.653 = -(\ln 2 / 87.7)\, t$ $t = 53.9$ years	**A1**
8(c)	advantage: less mass so less energy needed to launch probe	**B1**
	disadvantage: half-life shorter so will not provide power for as long	**B1**

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Question	Answer	Marks
9(a)	piezo-electric crystal	**B1**
	(ultrasound) wave causes shape change / vibrations (of crystal)	**B1**
	shape change / vibrations causes e.m.f. (which is detected)	**B1**
9(b)(i)	93 V	**A1**
9(b)(ii)	2.7×10^{7} rad s^{-1}	**A1**
9(c)(i)	kg m^{-2} s^{-1}	**B1**
9(c)(ii)	$\rho = Z / c = 1.7 \times 10^{6} / 1600$ = 1100 kg m^{-3}	**A1**
9(c)(iii)	intensity reflection coefficient ≈ 1 **or** Z_1 and Z_2 are very different	**B1**
	almost no / no ultrasound transmitted (into air filled cavity)	**B1**

Question	Answer	Marks
10(a)	brighter star could be closer (to Earth)	**B1**
	brighter star could have a greater luminosity (in the visible wavelengths)	**B1**
10(b)	object with known luminosity	**B1**
10(c)(i)	$\frac{660.9 - 656.3}{656.3} \approx \frac{v}{3.0 \times 10^8}$ leading to $2.1 \times 10^6\,\text{m s}^{-1}$	**B1**
10(c)(ii)	$v = H_0 d$	**C1**
	$d = 2.1 \times 10^6 / 2.3 \times 10^{-18}$ $= 9.1 \times 1023\,\text{m}$	**A1**
10(c)(iii)	wavelength has increased / light is redshifted	**B1**
	star within galaxy is moving away / receding (from Earth)	**B1**
	Universe is expanding	**B1**