Cambridge Assessment International Education

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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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)	$\phi = -\frac{GM}{r}$ $M = -\frac{-3.55 \times 10^7 \times 4800000}{6.67 \times 10^{-11}}$ $= 2.55 \times 10^{24}$ kg	**B1**
1(b)(iii)	$g = \frac{GM}{r^2}$ **or** $g = -\frac{\phi}{r}$	**C1**
	$= \frac{6.67 \times 10^{-11} \times 2.55 \times 10^{24}}{4800000^2}$ **or** $= \frac{3.55 \times 10^7}{4800000}$ $= 7.4$ 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**
	$T^2 = \frac{4\pi^2 r^3}{GM} = \frac{4\pi^2 \times (2.65 \times 10^7)^3}{6.67 \times 10^{-11} \times 2.55 \times 10^{24}} = 4.20 \times 10^9$	**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** $E = ½mv_0^2$ **and** $v_0 = \omega x_0$	**C1**
	$6.4 \times 10^{-3} = \frac{1}{2} \times 0.130 \times \omega^2 \times 0.015^2$ ($\omega^2 = 438$) ($\omega = 20.9$)	**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)**

Question	Answer	Marks
4(b)(iii)	$E_p = \dfrac{Q_1Q_2}{4\pi\varepsilon_o r} = \dfrac{96\times10^{-9}\times64\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.080}$ = 6.9×10^{-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**
	$= 18.2 / 12 = 1.5$ μF	**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. $\dfrac{4.95}{18.2} = e^{-5.2/(1.5\times10^{-6}R)}$ **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
	$\frac{6.63\times10^{-34}\times3.00\times10^{8}}{658\times10^{-9}} = -E_1 - (-3.40 \times 1.60 \times 10^{-19})$ $E_1 = -2.42 \times 10^{-19}$ 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**

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)	$\dfrac{660.9-656.3}{656.3} \approx \dfrac{v}{3.0\times10^{8}}$ leading to $2.1\times10^{6}\,\text{m s}^{-1}$	**B1**
10(c)(ii)	$v = H_0d$	**C1**
	$d = 2.1\times10^{6} / 2.3\times10^{-18}$ $= 9.1 \times 1023\,\text{m}$	**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**