Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/41**

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.

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This document consists of **16** printed pages.

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 independent 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 method 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 compensatory 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 answer 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 *Any point, 1 mark*	**B1**
	difference: • gravitational potential is (always) negative • electric potential can be positive or negative *Any point, 1 mark*	**B1**
1(b)(i)	$g = GM / r^2$	**M1**
	$E = Q / 4\pi\varepsilon_0 r^2$	**M1**
	algebra showing the elimination of r leading to $M / Q = (1 / 4\pi G\varepsilon_0)\ (g / E)$	**A1**
1(b)(ii)	$\alpha = 1 / (4\pi \times 6.67 \times 10^{-11} \times 8.85 \times 10^{-12}) = 1.35 \times 10^{20}$ (kg^2 C^{-2}) **or** $\alpha = (8.99 \times 10^{9}) / (6.67 \times 10^{-11}) = 1.35 \times 10^{20}$ (kg^2 C^{-2})	**A1**
1(c)(i)	$E = \alpha gQ / M$ $= (1.35 \times 10^{20} \times 9.81 \times 4.80 \times 10^{5}) / (5.98 \times 10^{24})$	**C1**
	$= 106$ N C^{-1} **or** 106 V m^{-1}	**A1**
1(c)(ii)	same (direction)	**B1**

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)	$r = 10.8 \times \sin 27° = 4.9\,\text{cm}$	**A1**
2(b)(ii)	$T \cos \theta = mg$ **or** $T \cos \theta = W$ **and** $W = mg$	**C1**
	$T \cos 27° = 0.29 \times 9.81$ 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 $= (T \sin \theta) / m$ $= (3.2 \times \sin 27°) / 0.29$	**C1**
	$= 5.0\,\text{m s}^{-2}$	**A1**

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**
	$T = 2\pi \times \sqrt{(0.049 / 5.0)}$ $= 0.62$ 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 *Any two points, 1 mark each*	**B2**
3(c)(i)	boiling point = 80 °C	**A1**
3(c)(ii)	$Q = Pt$ **and** $t = 21$ s (thermal energy supplied = 810 × 21 = 17000 J)	**C1**
	$c = Q / m\Delta\theta$	**C1**
	thermal energy absorbed by beaker = 42 × 0.84 × (80 – 25) (= 1940 J)	**C1**
	s.h.c. of liquid = [(810 × 21) – (42 × 0.84 × (80 – 25))] / [120 × (80 – 25)] = 2.3 J g^{-1} 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**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>4(a)</td><td>• 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)
Any two points, 1 mark each</td><td>B2</td></tr>
<tr><td rowspan="2">4(b)(i)</td><td>(general starting equation) $pV = nRT$</td><td>C1</td></tr>
<tr><td>$T = (2pV / nR)$ where R is the (molar) gas constant</td><td>A1</td></tr>
<tr><td rowspan="3">4(b)(ii)</td><td>sketch: straight vertical line XY from (V, 2p) to (V, p)</td><td>B1</td></tr>
<tr><td>straight horizontal line YZ from (V, p) to (2V, p)</td><td>B1</td></tr>
<tr><td>curve with gradient increasing from Z to X from (2V, p) to (V, 2p)</td><td>B1</td></tr>
<tr><td rowspan="5">4(b)(iii)</td><td>XY work done on gas correct (= 0)</td><td>B1</td></tr>
<tr><td>ZX increase in internal energy correct (= 0)</td><td>B1</td></tr>
<tr><td>YZ work done on gas correct (= $-pV$)</td><td>B1</td></tr>
<tr><td>XY increase in internal energy such that the increase in internal energy column adds up to zero</td><td>B1</td></tr>
<tr><td>all three thermal energies transferred such that $\Delta U = q + w$ in each row

(completely correct answer:
<table>
<tr><th>change</th><th>ΔU</th><th>Q</th><th>w</th></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>
)</td><td>B1</td></tr>
</table>

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 / τ) leading to τ = 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**

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**

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**

Question	Answer	Marks
8(a)(i)	specific acoustic impedance = 1200 × 1400 = 1.68×10^6 kg m^{-2} 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**

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 *Any two points, 1 mark each*	**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**
	$= (3.8 \times 10^{31}) / [4\pi \times (1.8 \times 10^{24})^2]$ $= 9.3 \times 10^{-19}$ W m^{-2}	**A1**
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)	$\Delta\lambda / \lambda = v / c$ $v = [(492 - 486) \times 3.00 \times 10^8] / 486$ ($v = 3.7 \times 10^6$ m s^{-1})	**C1**
	$H_0 = v / d$	**C1**
	$= (3.7 \times 10^6) / (1.8 \times 10^{24})$ $= 2.1 \times 10^{-18}$ s^{-1}	**A1**