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Cambridge International AS & A Level

PHYSICS	**9702/41**
Paper 4 A Level Structured Questions	**May/June 2022**
MARK SCHEME	
Maximum Mark: 100	

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Published

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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.
<u> </u>	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.

Annotations

✓	Indicates the point at which a mark has been awarded.
X	Indicates an incorrect answer or a point at which a decision is made not to award a mark.
XP	Indicates a physically incorrect equation ('incorrect physics'). No credit is given for substitution, or subsequent arithmetic, in a physically incorrect equation.

ECF	Indicates 'error carried forward'. Answers to later numerical questions can always be awarded up to full credit provided they are consistent with earlier incorrect answers. <u>Within</u> a section of a numerical question, ECF can be given after AE, TE and POT errors, but **not** after XP.
AE	Indicates an arithmetic error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
POT	Indicates a power of ten error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
TE	Indicates incorrect transcription of the correct data from the question, a graph, data sheet or a previous answer. For example, the value of 1.6×10^{-19} has been written down as 6.1×10^{-19} or 1.6×10^{19}. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
SF	Indicates that the correct answer is seen in the working but the final answer is incorrect as it is expressed to too few significant figures.
BOD	Indicates that a mark is awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done ('benefit of doubt').
CON	Indicates that a response is contradictory.
I	Indicates parts of a response that have been seen but disregarded as irrelevant.
M0	Indicates where an A category mark has not been awarded due to the M category mark upon which it depends not having previously been awarded.
^	Indicates where more is needed for a mark to be awarded (what is written is not wrong, but not enough). May also be used to annotate a response space that has been left completely blank.
SEEN	Indicates that a page has been seen.

Question	Answer	Marks
1(a)(i)	(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(a)(ii)	$g = F / m$	C1
A1	$F = GMm / r^2$ and so $g = [GMm / r^2] / m = GM / r^2$	A1
1(b)(i)	$g = (6.67 \times 10^{-11} \times 7.35 \times 10^{22}) / (1.74 \times 10^6)^2 = 1.62\ \text{N kg}^{-1}$	A1
1(b)(ii)	fields (due to Earth and the Moon) have equal magnitudes	B1
	fields (due to Earth and the Moon) are in opposite directions	B1
1(b)(iii)	distance of X from Earth = $(3.84 \times 10^8 - x)$	C1
	$(G \times)\ 7.35 \times 10^{22} / x^2 = (G \times)\ 5.98 \times 10^{24} / (3.84 \times 10^8 - x)^2$	C1
	$x = 3.8 \times 10^7\ \text{m}$	A1

Question	Answer	Marks
2(a)(i)	(vertically) downwards	**B1**
2(a)(ii)	magnetic force (on sphere) is perpendicular to its velocity	**B1**
	magnetic force perpendicular to velocity is the centripetal force **or** magnetic force perpendicular to velocity causes centripetal acceleration **or** acceleration perpendicular to velocity is centripetal (acceleration) **or** magnetic force does not change the speed of the sphere **or** magnetic force has constant magnitude	**B1**
2(b)	$mg = Eq$	**C1**
	$E = (1.6 \times 10^{-10} \times 9.81)/(0.27 \times 10^{-9})$ $= 5.8 \, \text{N C}^{-1}$	**A1**
2(c)	centripetal force = magnetic force **or** $Bqv = mv^2/r$	**B1**
	$B = mv/qr$	**C1**
	$= (1.6 \times 10^{-10} \times 0.78)/(0.27 \times 10^{-9} \times 3.4) = 0.14 \, \text{T}$	**A1**

Question	Answer	Marks
3(a)(i)	a gas that obeys $pV \propto T$	**M1**
	where p = pressure, V = volume, T = thermodynamic temperature	**A1**
3(a)(ii)	T = (273 + 17) K	**C1**

	$n = pV/RT$
	
	    $= (1.2 \times 10^5 \times 0.24)/[8.31 \times (273 + 17)]$
	
	    = 12 mol
		A1

3(b)(i)	work done $= p\Delta V$	**C1**
	$= 1.2 \times 10^5 \times (0.24 - 0.08) = 19200$ J (= 19.2 kJ)	**A1**
3(b)(ii)	AB work done correct (19.2)	**A1**
	BC work done correct (0)	**A1**
	CA increase in internal energy correct (0) **and** CA thermal energy correct (31.6)	**A1**
	AB increase in internal energy calculated correctly from work done – 48.0	**A1**
	BC increase in internal energy correctly calculated so the final column adds up to zero **and** BC thermal energy same as increase in internal energy (Fully correct table: <table><tr><td>AB</td><td>19.2</td><td>−48.0</td><td>−28.8</td></tr><tr><td>BC</td><td>0</td><td>28.8</td><td>28.8</td></tr><tr><td>CA</td><td>−31.6</td><td>31.6</td><td>0</td></tr></table>)	**A1**

Question	Answer	Marks
4(a)	straight line through origin shows that a is proportional to x	**B1**
	negative gradient shows that a is in opposite direction to x	**B1**
4(b)(i)	$a_0 = \omega^2 x_0$ **or** $a = -\omega^2 x$ **or** $\omega^2 = -$ gradient	**C1**
	$\omega = \sqrt{(0.40 / 0.050)}$ $= 2.8 \text{ rad s}^{-1}$	**A1**
4(b)(ii)	$k = \omega^2 L$ $= 2.8^2 \times 1.24$	**C1**
	$= 9.7 \text{ m s}^{-2}$	**A1**
4(c)	(increasing L causes) ω to decrease **or** energy $(= \frac{1}{2}\, m\omega^2 x_0^2) = \frac{1}{2}\, mk x_0^2 / L$ (and L increases)	**M1**
	so amplitude increases	**A1**

Question	Answer	Marks
5(a)(i)	conversion (from a.c.) to d.c.	B1
5(a)(ii)	full-wave (rectification)	B1
5(b)(i)	P labelled – **and** Q labelled +	B1
5(b)(ii)	V_{OUT} scale labelled 4 and 8 on the 2 cm tick marks	B1
	$T = 2\pi / \omega$ $\quad = 2\pi / 25\pi$ $\quad = 0.08$ s	C1
	t scale labelled 0.02, 0.04, 0.06, 0.08, 0.10, 0.12 on the 2 cm tick marks	A1
5(c)(i)	correct symbol used for capacitor and capacitor connected in parallel with the 1.2 kΩ resistor.	B1
5(c)(ii)	straight lines or curves, with negative decreasing gradients, drawn between adjacent peaks, from top of first peak to meet line going up to next peak	B1
	lines, from one peak to the line going up to the next peak, show a drop in p.d. of 1½ small squares	B1
5(c)(iii)	$V = 0.90 \times 6.0$ (= 5.4 V) **or** discharge time (for each cycle) = 0.034 s	C1
	$V = V_0 \exp(-t/RC)$ $5.4 = 6.0 \exp[-0.034 / (1.2 \times 10^3 \times C)]$	C1
	$C = 2.7 \times 10^{-4}$ F	A1

Question	Answer	Marks
6(a)	product of (magnetic) flux density and area	**M1**
	where area is perpendicular to the (magnetic) field	**A1**
6(b)(i)	$N\Phi = BAN$	**C1**
	$= 400 \times 10^{-3} \times 0.12^2 \times 8$	**C1**
	$= 0.046$ Wb	**A1**
6(b)(ii)	(line is a) straight line	**B1**
6(b)(iii)	(induced) e.m.f. = rate of change of flux linkage	**C1**
	e.m.f. $= N\Phi/t$ $= 0.046 / 0.60$ $= 0.077$ V	**A1**
6(c)	(induced e.m.f. causes) current flow (in the coil)	**B1**
	either	
	current (in magnetic field) causes forces to act on the coil	**B1**
	(opposite sides of) coil forced inwards	**B1**
	or	
	current causes dissipation of energy in the resistance of the coil	**(B1)**
	temperature of the coil rises	**(B1)**

Question	Answer	Marks
7(a)	quantum of energy	M1
	of electromagnetic radiation	A1
7(b)(i)	photoelectric effect	B1
7(b)(ii)	• there is a frequency below which no electrons are emitted **or** threshold frequency = 5.4×10^{14} Hz • work function of the metal = 3.6×10^{-19} J (or 2.2 eV) • E_{MAX} increases (linearly) with (increasing) frequency • gradient of the line is the Planck constant **or** gradient of the line is 6.7×10^{-34} J s *Any three bullet points, 1 mark each*	B3
7(c)(i)	different threshold frequency	B1
	(line has) same gradient but different intercept	B1
7(c)(ii)	photons have same energy	B1
	line unchanged	B1

Question	Answer	Marks
8(a)(i)	energy required to separate the nucleons (in the nucleus)	**M1**
	to infinity	**A1**
8(a)(ii)	curve starting close to the origin and forming a single peak	**B1**
	peak shown to left of centre, with steep line on LHS of peak and shallow line on RHS of peak	**B1**
8(b)(i)	fusion	**B1**
8(b)(ii)	both particles have low A values **or** both particles are at left-hand end of graph	**B1**
	He-3 has higher binding energy (per nucleon) than H-2	**B1**
8(c)	Δm = $[(2 \times 2.014102) - (3.016029 + 1.008665)]$ u (= 0.00351 u)	**C1**
	$E = \Delta mc^2$	**C1**
	= $0.00351 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$ (= 5.24×10^{-13} J)	**C1**
	1.00 mol of deuterium forms 0.500 mol of helium-3	**C1**
	total energy = $0.500 \times 6.02 \times 10^{23} \times 5.24 \times 10^{-13}$ = 1.58×10^{11} J	**A1**

Question	Answer	Marks
9(a)(i)	electrons are accelerated (by an applied p.d.)	B1
	electrons hit target	B1
	X-rays produced when electrons decelerate	B1
9(a)(ii)	images of the multiple sections are combined to create a 3-D image	B1
9(b)(i)	$I = I_0 \exp(-\mu x)$	C1
	$= I_0 \exp(-0.89 \times 5.6)$	A1
	$= 0.0068\, I_0$	
9(b)(ii)	$I = I_0 \exp(-2.4 \times 3.4) \times \exp(-0.89 \times 3.2)$	C1
	$= 1.7 \times 10^{-5}\, I_0$	A1
9(c)	comparison of intensities or values in **(b)** leading to conclusion consistent with these values	B1

Question	Answer	Marks
10(a)	wavelength of maximum intensity is inversely proportional to (thermodynamic) temperature	B1
10(b)(i)	λ_{MAX} = 0.50 μm for A **and** 0.65 μm for B	C1
A1	T = 5800 × (0.50 / 0.65) = 4500 K	A1
10(b)(ii)	(star B has) greater peak / average wavelength	B1
	(star B looks) redder	B1
10(c)(i)	apparent wavelength is greater **or** wavelength is greater than known value	B1
	(due to) movement of star away (from observer)	B1
10(c)(ii)	by examining the (lines in the) spectrum (of light from the star)	B1
	and comparing with known spectrum	B1