Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 2022**

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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[Turn over

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.

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. Within 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)	work (done) per unit mass	**B1**
	work (done on mass) in moving mass from infinity (to the point)	**B1**
1(a)(ii)	$E_P = \phi m$ $E_P = (-GM/r) \times m = -GMm/r$ **or** $\phi = -GM/r$ **and** $E_P = \phi m = -GMm/r$	**B1**
1(b)(i)	$\Delta E_P = 6.67 \times 10^{-11} \times 1.99 \times 10^{30} \times 2.20 \times 10^{14} \times [1/(6.38 \times 10^{10}) - 1/(8.44 \times 10^{11})]$	**C1**
	$= 4.23 \times 10^{23}$ J	**A1**
1(b)(ii)	(gravitational) force is attractive so decrease **or** (gravitational) force does work so decrease	**B1**
1(b)(iii)	$\Delta E_P = ½m(v_2^2 - v_1^2)$	**C1**
	$4.23 \times 10^{23} = ½ \times 2.20 \times 10^{14} \times (v^2 - 34\,100^2)$	**C1**
	v (= 70 800 m s^{-1}) = 70.8 km s^{-1}	**A1**
1(c)	both PE and KE equations include m, so path is unchanged	**B1**

Question	Answer	Marks
2(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**
2(b)(i)	(electric) force is perpendicular to velocity (of particles)	**B1**
	force (perpendicular to velocity) causes centripetal acceleration **or** force does not change the speed of the particles **or** force has constant magnitude	**B1**
2(b)(ii)	$F = e^2 / 4\pi\varepsilon_0 x^2$	**C1**
	$= (1.60 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (2 \times 1.59 \times 10^{-10})^2]$ $= 2.28 \times 10^{-9}$ N	**A1**
2(b)(iii)	$F = mr\omega^2$ **and** $\omega = 2\pi / T$ **or** $F = mv^2 / r$ **and** $v = 2\pi r / T$	**C1**
	$F = 4\pi^2 mr / T^2$ $T = \sqrt{[4\pi^2 \times 9.11 \times 10^{-31} \times 1.59 \times 10^{-10} / (2.28 \times 10^{-9})]}$	**C1**
	$= 1.58 \times 10^{-15}$ s	**A1**
2(c)(i)	• electron and positron interact • positron is anti-particle of electron • (pair) annihilation occurs *Any two points, 1 mark each*	**B2**
	mass of the electron and positron converted into photon energy	**B1**
2(c)(ii)	PET scanning	**B1**

Question	Answer	Marks
3(a)	(thermal) energy per unit mass	**B1**
	energy to change state between liquid and gas at constant temperature	**B1**
3(b)(i)	$q = mL = 0.37 \times 2.3 \times 10^6$ $= 8.5 \times 10^5$ J	**A1**
3(b)(ii)	$pV = nRT$ **and** $T = 373$ K	**C1**
	$n = 370 / 18$	**C1**
	$V = [(370 / 18) \times 8.31 \times 373] / (1.0 \times 10^5) = 0.64$ m^3	**A1**
3(b)(iii)	$w = p\Delta V$	**C1**
	$= 1.0 \times 10^5 \times 0.64$ $= 6.4 \times 10^4$ J	**A1**
3(b)(iv)	(water does work against atmosphere so) work done on water is negative	**B1**
	increase in internal energy = $(8.5 – 0.64) \times 10^5 = 7.9 \times 10^5$ J	**A1**
3(c)	valid reasoning of how work done by water is affected	**M1**
	correct use of first law to draw conclusion about effect on specific latent heat that is consistent with work done	**A1**

Question	Answer	Marks
4(a)	oscillations (of object) at maximum amplitude	**B1**
	when driving frequency equals natural frequency (of object)	**B1**
4(b)(i)	$T = 2\pi / \omega$	**C1**
	$= 2\pi / 5.0\pi$ $= 0.40$ s	**A1**
4(b)(ii)	displacement scale labelled –1.0, –0.5, (0), 0.5, 1.0 on the 2 cm tick marks	**B1**
	t scale labelled 0.2, 0.4, 0.6, 0.8, 1.0, 1.2 on the 2 cm tick marks	**B1**
4(b)(iii)	$\phi = 2\pi\Delta t / T$ $= 2\pi \times 0.10 / 0.40$ **or** $2\pi \times 0.30 / 0.40$	**C1**
	= 1.6 rad **or** 4.7 rad	**A1**

Question	Answer	Marks
5(a)	charge / potential (difference)	**M1**
	charge is charge on one plate, <u>and</u> potential is p.d. across the plates	**A1**
5(b)	p.d. across both capacitors = E	**B1**
	$Q_T = Q_1 + Q_2$	**B1**
	$C_T E = C_1 E + C_2 E$ hence $C_T = C_1 + C_2$	**B1**
5(c)(i)	$[(1 / 22) + (1 / 47)]^{-1} = 15\ \mu F$	**A1**
5(c)(ii)	energy = $\frac{1}{2} C V^2$	**C1**
	$= \frac{1}{2} \times 15 \times 10^{-6} \times 12^2$ $= 1.1 \times 10^{-3}$ J	**A1**
5(c)(iii)	initial p.d. (across 22 μF) $= 12 \times (15 / 22)$ $= 8.2$ V **or** final p.d. across both capacitors $= 6.0 \times (22 / 15)$ $= 8.8$ V	**C1**
	$V = V_0 \exp [- t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$	**C1**
	$6.0 = 8.2 \exp [- t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$ **or** $8.8 = 12 \exp [- t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$ $t = 13$ s	**A1**

Question	Answer	Marks
6(a)	there must be a current (in the wire)	**B1**
	(wire) must be at a non-zero angle to the magnetic field	**B1**
6(b)(i)	arrow from X pointing horizontally to the left	**B1**
	arrow from Y pointing diagonally upwards and to the left at about 45°	**B1**
	arrow from Z pointing horizontally to the right	**B1**
6(b)(ii)	(flux densities at W and X are approximately) equal	**B1**
	(flux density at) Y greater than (flux density at) Z	**B1**
6(c)	current in wire creates magnetic field around wire	**B1**
	(each) wire sits in the magnetic field created by the other	**B1**
	(for each wire,) current / wire is perpendicular to magnetic field (due to other wire), (so) experiences a (magnetic) force	**B1**

Question	Answer	Marks
7(a)	induced e.m.f. is (directly) proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
7(b)	V_2 stepped, all at non-zero values, between $t = 0$ and $t = 0.40$ s	**B1**
	V_2 shown with same non-zero magnitude up to $t = 0.15$ s and after $t = 0.25$ s but with a different magnitude between these times	**B1**
	V_2 shown with a magnitude between $t = 0.15$ s and $t = 0.25$ s that is three times the magnitude before $t = 0.15$ s and after $t = 0.25$ s	**B1**
	V_2 shown with same sign up to $t = 0.15$ s and after $t = 0.25$ s, and opposite sign in between	**B1**
7(c)(i)	changing current in coil causes changing (magnetic) field **or** changing (magnetic) flux causes induced e.m.f. in ring	**B1**
	induced e.m.f. in ring causes current in ring	**B1**
	(magnetic) field due to (induced) current in ring interacts with (coil's) field to cause upwards force (on ring) **or** (induced) current in ring perpendicular to (coil's magnetic) field causes upwards force (on ring)	**B1**
7(c)(ii)	both magnetic fields reverse direction so ring still jumps up **or** current (in ring) and (coil's) field both reverse so ring still jumps up	**B1**

Question	Answer	Marks
8(a)(i)	photoelectric effect	**B1**
8(a)(ii)	electron diffraction	**B1**
8(b)(i)	$\lambda = h / p$	**C1**
	$p = 4 \times 1.66 \times 10^{-27} \times 6.2 \times 10^{7}$ $(= 4.1 \times 10^{-19}\ \text{N s})$	**C1**
	$\lambda = 6.63 \times 10^{-34} / 4.1 \times 10^{-19}$ $= 1.6 \times 10^{-15}\ \text{m}$	**A1**
8(b)(ii)	line with negative gradient throughout	**B1**
	curve asymptotic to both axes with non-zero λ at $v = 6.2 \times 10^{7}\ \text{m s}^{-1}$	**B1**
8(c)	(de Broglie) wavelength negligible compared with width of doorway	**B1**

Question	Answer	Marks
9(a)(i)	speed is (directly) proportional to distance	**M1**
	where speed is speed of recession of galaxy (from observer) and distance is distance of galaxy away from observer	**A1**
9(a)(ii)	wavelengths (of spectral lines) are greater (than their known values)	**B1**
	redshift shows stars (in distant galaxies) moving away from Earth	**B1**
9(b)	(all) parts of Universe moving away from each other	**B1**
	more distant objects are moving away faster	**B1**
	matter must have been close together / very dense in the past	**B1**

Question	Answer	Marks
10(a)	spontaneous emission of (ionising) radiation	**B1**
	emission from unstable nucleus	**B1**
10(b)(i)	curve with decreasing negative gradient passing through (0, N_0)	**B1**
	curve passing through (T, $0.5N_0$)	**B1**
	curve passing through ($2T$, $0.25N_0$) **and** ($3T$, $0.125N_0$)	**B1**
10(b)(ii)	line through origin with positive gradient	**B1**
	straight line passing through (N_0, A_0)	**B1**
10(c)(i)	activity	**B1**
10(c)(ii)	decay constant	**B1**
10(d)	$N = N_0 \exp(-\ln 2 \times 1.70T / T)$	**C1**
	$N / N_0 = 0.31$	**A1**