Cambridge International AS & A Level

PHYSICS | **9702/42**

Paper 4 A Level Structured Questions | **October/November 2022**

MARK SCHEME

Maximum Mark: 100

Published

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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)	force per unit mass	**B1**
1(b)(i)	lines drawn are radial from the surface	**B1**
	arrows show pointing towards planet	**B1**
1(b)(ii)	field lines show force (on satellite) is towards centre of planet **or** velocity of satellite is perpendicular to field lines	**B1**
	(gravitational) force perpendicular to velocity causes centripetal <u>acceleration</u>	**B1**
1(c)(i)	T = 24 hours	**C1**
	$a = r\omega^2$ **and** $\omega = 2\pi / T$ **or** $a = v^2 / r$ **and** $v = 2\pi r / T$ **or** $a = 4\pi^2 r / T^2$	**C1**
	$a = (4\pi^2 \times 6.4 \times 10^6) / (24 \times 60 \times 60)^2$ $= 0.034\ \text{m s}^{-2}$	**A1**
1(c)(ii)	identification of the two forces acting on the object as gravitational force and (normal) contact force	**M1**
	gravitational force and normal contact force are in opposite directions, and their resultant causes the (centripetal) acceleration	**A1**

Question	Answer	Marks
2(a)	(thermal) energy per unit mass (to cause temperature change)	**B1**
	(thermal) energy per unit change in temperature	**B1**
2(b)(i)	work done correct (0)	**B1**
	increase in internal energy correct (+*E*)	**B1**
2(b)(ii)	work done correct (–*W*) **and** increase in internal energy same as **(b)(i)**	**B1**
	thermal energy correct so that it adds to work done to give increase in internal energy	**B1**
2(c)	more thermal energy needed so specific heat capacity is greater	**B1**

Question	Answer	Marks
3(a)	p = pressure (of gas), V = volume (of gas) **and** k = Boltzmann constant	**B1**
	N = number of molecules	**B1**
	T = thermodynamic temperature	**B1**
3(b)	($pV = NkT$ and $pV = \frac{1}{3}Nm<c^2>$ leading to) $NkT = \frac{1}{3}Nm<c^2>$	**M1**
	algebra leading to $(3/2)kT = \frac{1}{2}m<c^2>$ **and** use of $\frac{1}{2}m<c^2> = E_K$ leading to $(3/2)kT = E_K$	**A1**
3(c)(i)	$T = 296\ \text{K}$	**C1**
	$\frac{1}{2}m<c^2> = (3/2)kT$ $\frac{1}{2} \times 5.31 \times 10^{-26} \times u^2 = (3/2) \times 1.38 \times 10^{-23} \times 296$	**C1**
	$u = 480\ \text{m s}^{-1}$	**A1**
3(c)(ii)	line passing through (P, u)	**B1**
	horizontal straight line	**B1**

Question	Answer	Marks
4(a)(i)	x_0 = 8.0 cm	A1
4(a)(ii)	$\omega = 2\pi / T$	C1
	$= 2\pi / 4.0 = 1.6\ \text{rad s}^{-1}$	A1
4(a)(iii)	$E = ½m\omega^2 x_0^2$	C1
	$= ½ \times 36 \times 1.6^2 \times 0.080^2$	C1
	= 0.29 J	A1
4(b)	dome-shaped curve, starting and ending at E_K = 0	B1
	maximum E_K shown as 0.29 J	B1
	position of peak shown at *h* = 10.0 cm	B1
	line intercepts *h*-axis at *h* = 2.0 cm and at *h* = 18.0 cm	B1

Question	Answer	Marks
5(a)	work done per unit charge	**B1**
	work done (on charge) in moving positive charge from infinity (to the point)	**B1**
5(b)(i)	radius = 0.060 m	**A1**
5(b)(ii)	$V = Q / 4\pi\varepsilon_0 x$ $Q = (–)\ 850 \times 4\pi \times 8.85 \times 10^{–12} \times 0.060$ **or** $Q = (–)\ 850 \times 0.060 / 8.99 \times 10^9$ (*any correct pair of V and x values from curve*)	**C1**
	$Q = –\ 5.7 \times 10^{–9}$ C	**A1**
5(c)(i)	$E_P = Q^2 / 4\pi\varepsilon_0 x$ $= (5.67 \times 10^{–9})^2 / (4\pi \times 8.85 \times 10^{–12} \times 0.46)$	**C1**
	$= 6.3 \times 10^{–7}$ J	**A1**
5(c)(ii)	• force is repulsive so spheres move apart • force in direction of motion so speed increases • potential energy converted to kinetic energy so speed increases • force decreases with distance so acceleration decreases • momentum is conserved (at zero) (and masses are equal) so velocities are always equal and opposite *Any three points, 1 mark each*	**B3**

Question	Answer	Marks
6(a)	• p.d. across resistor = p.d. across capacitor • current (in resistor) proportional to p.d. across it • current causes capacitor to lose charge • charge (on capacitor) proportional to p.d. so p.d. decreases *Any two points, 1 mark each*	**B2**
	rate of change of p.d. decreases as p.d. decreases	**B1**
6(b)	Q_0 = 0.90 mC **and** at t = one time constant, $Q = Q_0$ exp (–1)	**B1**
	at t = one time constant, Q = 0.90 exp (–1) = 0.33 mC	**M1**
	evidence of graph reading: when Q = 0.33 mC, t = 5.5 s	**A1**
	or	
	evidence of two correct sets of readings for Q and t from the graph	**(B1)**
	correct substitution of Q and t values into $Q_2 = Q_1 \exp [(t_1 - t_2) / \tau]$	**(M1)**
	calculation to give τ = 5.5 s	**(A1)**
	or	
	read-off of half-life as 3.75 s	**(B1)**
	use of $Q = Q_0 \exp (-t / \tau)$ to show that τ = half-life / ln 2	**(M1)**
	τ = 3.75 / ln 2 = 5.4 s	**(A1)**

Question	Answer	Marks
6(b)	**or**	
	tangent drawn on *Q*–*t* graph and value of *Q* at exact same time as tangent read from graph	**(M1)**
	gradient of tangent correctly calculated	**(A1)**
	$\tau = Q$ / gradient used to correctly calculate a value for τ as 5.5 s	**(A1)**
6(c)(i)	$C = Q / V$	**C1**
	$= [(0.90 \times 10^{-3}) / 7.5] = 1.2 \times 10^{-4}$ C = 120 μF	**A1**
6(c)(ii)	$R = \tau / C$	**C1**
	$= 5.5 / (1.2 \times 10^{-4})$ (= 45 800 Ω) = 46 kΩ	**A1**

Question	Answer	Marks
7(a)	force per unit current	**M1**
	force per unit length	**M1**
	current / wire is perpendicular to (magnetic) field (lines)	**A1**
7(b)(i)	current (in coil) is perpendicular to magnetic field (so force on wire)	**B1**
	force (on wire) is perpendicular to current and field (so is vertical) **or** current and field are both horizontal (so force is vertical)	**B1**
7(b)(ii)	$NBIL = mg$	**C1**
	$B = (2.16 \times 10^{-3} \times 9.81) / (40 \times 3.94 \times 0.0300)$	**C1**
	$= 4.48 \times 10^{-3}$ T	**A1**
7(b)(iii)	(magnetic) forces (on balance and newton meter) are (equal and) opposite	**B1**
	reading $= 0.563 - (2.16 \times 10^{-3} \times 9.81)$ $= 0.542$ N	**A1**

Question	Answer	Marks
8(a)	direction of induced e.m.f.	**M1**
	such as to (produce effects that) oppose the change that caused it	**A1**
8(b)(i)	X = 0.85 A	**A1**
	Y = $2\pi / 0.040$	**C1**
	= 160 rad s^{-1}	**A1**
8(b)(ii)	two cycles of a sinusoidal curve with a period of 0.040 s	**B1**
	correct phase (i.e. V_2 max / min at t = 0, 0.02, 0.04, 0.06 and 0.08 s, and V_2 zero at t = 0.01, 0.03, 0.05, 0.07 s)	**B1**
	maximum / minimum V_2 shown (consistently) at ± 6.5 V	**B1**
8(b)(iii)	(magnitude of) V_2 is proportional to rate of change of (magnetic) flux	**B1**
	• V_2 is proportional to <u>gradient</u> of I_1–t curve • V_2 has maximum magnitude when I_1–t curve is steepest • V_2 is zero when I_1–t curve is horizontal / a maximum or minimum • V_2 changes sign when sign of gradient of I_1–t curve changes *Any two points, 1 mark each*	**B2**

Question	Answer	Marks
9(a)(i)	• energy of photon has a corresponding frequency • change in electron energy level emits a single photon • photon energy = difference in energy levels • discrete frequencies must have come from discrete energy gaps • discrete energy changes imply discrete energy levels *Any three points, 1 mark each*	**B3**
9(a)(ii)	transition (to – 3.400 eV) from X corresponds to 658 nm line	**C1**
	$E_1 - E_2 = hc / \lambda$	**C1**
	$E_1 - (-3.400) = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (658 \times 10^{-9} \times 1.60 \times 10^{-19})$ and so $E_1 = -1.51$ eV (*full substitution and answer needed*)	**A1**
9(b)(i)	redshift	**B1**
9(b)(ii)	moving away (from observer)	**B1**
9(b)(iii)	$\Delta\lambda / \lambda = v / c$ e.g. for 658 nm line: $\Delta\lambda = 686 - 658$ (= 28 nm) (*other lines may be used*)	**C1**
	$28 / 658 = v / (3.00 \times 10^{8})$ (*other lines may be used*)	**C1**
	$v = 1.3 \times 10^{7}$ m s^{-1}	**A1**
9(c)	$v = H_0 d$	**C1**
	$H_0 = (1.3 \times 10^{7}) / (5.7 \times 10^{24})$ $= 2.3 \times 10^{-18}$ s^{-1}	**A1**

Question	Answer	Marks
10(a)(i)	introduction of tracer (into the body)	**M1**
	containing a β^+ emitter	**A1**
10(a)(ii)	positron interacts with electron	**B1**
	(pair) annihilation occurs	**B1**
	mass of particles converted into gamma photons	**B1**
10(b)	(annihilation of electron and positron) produces two photons	**B1**
	$E = (\Delta)mc^2$	**B1**
	$E = hf$ **and** $f = c / \lambda$ **or** $E = hc / \lambda$	**B1**
	$\lambda = \{[2\times]\ 6.63 \times 10^{-34} \times 3.00 \times 10^8\} / \{[2\times]\ 9.11 \times 10^{-31} \times (3.00 \times 10^8)^2\}$ $= 2.4(3) \times 10^{-12}$ m or 2.4(3) pm (*full substitution and answer with unit needed*)	**B1**