# Cambridge International AS & A Level

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| **PHYSICS** | **9702/41** |
| Paper 4 A Level Structured Questions | **October/November 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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## 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.<br><br>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) | $F = (Gm_1m_2) / r^2$ | **M1** |
| | where $G$ is the gravitational constant | **A1** |
| 1(b) | gravitational force provides the centripetal force | **B1** |
| | $mR\omega^2 = GMm / R^2$ **and** $\omega = 2\pi / T$<br>**or**<br>$mv^2 / R = GMm / R^2$ **and** $v = 2\pi R / T$<br>**or**<br>$4\pi^2 mR / T^2 = GMm / R^2$ | **M1** |
| | correct completion of algebra to get $T^2 = (4\pi^2 / GM) R^3$, with identification of $(4\pi^2 / GM)$ as $k$ | **A1** |
| 1(c)(i) | $(24 \times 3600)^2 = (4\pi^2 \times R^3) / (6.67 \times 10^{-11} \times 6.0 \times 10^{24})$ | **C1** |
| | $R = 4.2 \times 10^7$ m | **A1** |
| 1(c)(ii) | (orbit) must be above the Equator | **B1** |
| | (direction) must be from west to east | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 2(a) | • resistance of a metal<br>• volume of a gas at constant pressure<br>• e.m.f. of a thermocouple<br>*Any two points, 1 mark each* | **B2** |
| 2(b)(i) | $Q = mc\Delta T$ | **C1** |
| | evidence of realisation that $Q$ lost by water = $Q$ gained by mercury | **C1** |
| | $18.7 \times 4.18 \times (37.4 - T) = 6.94 \times 0.140 \times (T - 23.0)$ | **C1** |
| | $T = 37.2\,°C$ | **A1** |
| 2(b)(ii) | use a liquid with a lower (specific) heat capacity (than mercury)<br>**or**<br>use a smaller mass of mercury | **B1** |
| 2(c)(i) | depends on properties of a real substance | **B1** |
| | 0 °C is not absolute zero | **B1** |
| 2(c)(ii) | ideal gas | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 3(a) | $a = -\omega^2 x$ | **M1** |
| | $a$ = acceleration, $x$ = displacement from equilibrium position and $\omega$ = angular frequency | **A1** |
| 3(b)(i) | $x_0 = 0.12$ m | **A1** |
| 3(b)(ii) | $v = \omega\sqrt{(x_0^2 - x^2)}$<br>two ($x$, $v$) pairs correctly read from Fig. 3.2 (one may be ($x_0$, 0) or value of $x_0$ from **(i)**) | **C1** |
| | e.g. $0.20 = \omega\sqrt{(0.12^2 - 0)}$ leading to $\omega = 1.7\ \text{rad s}^{-1}$ | **A1** |
| 3(b)(iii) | $E = ½M\omega^2 x_0^2$ | **C1** |
| | $0.050 = ½ \times M \times 1.67^2 \times 0.12^2$<br>$M = 2.5$ kg | **A1** |
| | **or** | |
| | $(E_K)_{max} = ½Mv_0^2$ | **(C1)** |
| | $0.050 = ½\ M \times 0.20^2$<br>$M = 2.5$ kg | **(A1)** |
| 3(c)(i) | loss of (total) energy (of system) | **B1** |
| | due to resistive forces | **B1** |
| 3(c)(ii) | closed loop surrounding the origin with maximum $x$ at ± 0.060 m passing through $v = 0$ | **B1** |
| | maximum velocity shown as ± 0.10 m s$^{-1}$ passing through $x = 0$ | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 4(a) | (field line indicates) direction of force | **B1** |
| | force on a positive charge | **B1** |
| 4(b)(i) | one straight line perpendicular to plates, starting on one plate and finishing on the other | **B1** |
| | five straight lines perpendicular to plates between the plates, uniformly spaced | **B1** |
| | downwards arrows on lines | **B1** |
| 4(b)(ii) | $E = V / d$ | **C1** |
| | $= 2400 / 0.046$<br>$= 5.2 \times 10^4\ \text{N C}^{-1}$ | **A1** |
| 4(c)(i) | smooth curve in region of field and straight line outside field | **B1** |
| | direction of deflection shown as downwards in region of field | **B1** |
| 4(c)(ii) | helium nucleus has double the charge but four times the mass | **B1** |
| | velocity parallel to plates same and acceleration perpendicular to plates smaller (for helium) | **B1** |
| | final speed is lower (for helium) | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 5(a)(i) | $Q = CV$ | **C1** |
| | $Q_0 = 24 \times 470 \times 10^{-6}$<br>$= 0.011$ C | **A1** |
| 5(a)(ii) | $I_0 = 24 / 5600$<br>$= 4.3 \times 10^{-3}$ A | **A1** |
| 5(a)(iii) | $\tau = RC$ | **C1** |
| | $= 5600 \times 470 \times 10^{-6}$<br>$= 2.6$ s | **A1** |
| 5(a)(iv) | line with negative gradient throughout passing through $(0, I_0)$ | **B1** |
| | exponential decay curve asymptotic to *t*-axis | **B1** |
| 5(b)(i) | current in wire P gives rise to a magnetic field | **B1** |
| | as current (in P) changes, wire Q cuts (magnetic) flux (of wire P) | **B1** |
| | cutting magnetic flux causes induced e.m.f. (across Q) | **B1** |
| 5(b)(ii) | sketch shows line with a negative gradient throughout | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 6(a)(i) | PQRS and WXYZ | **B1** |
| 6(a)(ii) | force on charge carriers is perpendicular to both (magnetic) field and current | **B1** |
| | as charge carriers are deflected to one side, an electric field is set up | **B1** |
| | (steady $V_H$ when) electric and magnetic forces on charge carriers are equal (and opposite) | **B1** |
| 6(b)(i) | $n$: number density of charge carriers | **B1** |
| | $t$: distance PW (or SZ or QX or RY) | **B1** |
| | $q$: charge on each charge carrier | **B1** |
| 6(b)(ii) | $V_H$ inversely proportional to $t$ | **B1** |
| | (so $t$ needs to be small for) $V_H$ to be large enough to measure | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 7(a)(i) | peak voltage = $4.2 \times \sqrt{2}$<br>(= 5.9 V) | B1 |
| | power = $V^2 / R$<br>= $5.9^2 / 760$ = 0.046 W or 46 mW | A1 |
| 7(a)(ii) | sketch shows peak(s) in power at 46 mW | B1 |
| | correct shape (sinusoidal wave sitting on *t*-axis) | B1 |
| | four cycles of repeating pattern shown, with $P$ = 0 at 0, 10, 20, 30, 40 μs | B1 |
| 7(a)(iii) | line is symmetrical about 23 mW | B1 |
| 7(b)(i) | (alternating p.d. makes) the crystal vibrate | B1 |
| | vibrations (of crystal) causes air to vibrate | B1 |
| | frequency is in ultrasound range | B1 |
| 7(b)(ii) | (air makes) crystal vibrate, which causes an e.m.f. to be generated across the (second) crystal | B1 |

| Question | Answer | Marks |
|---|---|---|
| 8(a) | photon energy (to remove electron) | **B1** |
| | minimum energy to remove electron<br>**or**<br>energy to remove electron from surface<br>**or**<br>energy to remove electron with zero kinetic energy | **B1** |
| 8(b)(i) | photon energy = $hf$ | **C1** |
| | number per unit time = $8.36 \times 10^{-3} / (1.36 \times 10^{15} \times 6.63 \times 10^{-34})$<br>$= 9.27 \times 10^{15}\ \text{s}^{-1}$ | **A1** |
| 8(b)(ii) | $hf = \Phi + E_{MAX}$ | **C1** |
| | $\Phi = (1.36 \times 10^{15} \times 6.63 \times 10^{-34}) - (3.09 \times 10^{-19})$<br>$= 5.93 \times 10^{-19}\ \text{J}$ | **A1** |
| 8(c)(i) | greater photon energy (and same work function) | **M1** |
| | so maximum kinetic energy is increased | **A1** |
| 8(c)(ii) | (greater photon energy and same power so) lower number of photons (per unit time) | **M1** |
| | (each electron absorbs one photon) so lower rate of emission | **A1** |

| Question | Answer | Marks |
|---|---|---|
| 9(a) | total power of radiation emitted (by the star) | **B1** |
| 9(b)(i) | $F = L / (4\pi d^2)$ | **C1** |
| | $= 9.86 \times 10^{27} / [4\pi \times (8.14 \times 10^{16})^2]$<br><br>$= 1.18 \times 10^{-7}$ W m$^{-2}$ | **A1** |
| 9(b)(ii) | $L = 4\pi\sigma r^2 T^4$<br><br>$9.86 \times 10^{27} = 4 \times \pi \times 5.67 \times 10^{-8} \times r^2 \times 9830^4$ | **C1** |
| | radius = $1.22 \times 10^9$ m | **A1** |
| 9(c) | wavelength of peak intensity determined (from spectrum of star) | **B1** |
| | wavelength of peak intensity from object of known temperature determined | **B1** |
| | Wien's displacement law used<br>**or**<br>wavelength of peak intensity inversely proportional to temperature | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 10(a)(i) | cannot predict when a (particular) nucleus will decay<br>**or**<br>cannot predict which nucleus will decay next | **B1** |
| 10(a)(ii) | not affected by external / environmental factors | **B1** |
| 10(b)(i) | line fluctuates<br>**or**<br>trend is a straight line | **B1** |
| 10(b)(ii) | straight line of best fit drawn on Fig. 10.1 | **B1** |
| 10(b)(iii) | $M = M_0 \exp(-\lambda t)$<br><br>so $\ln M = \ln M_0 - \lambda t$ so gradient = $-\lambda$ (and magnitude of gradient = $\lambda$) | **B1** |
| 10(b)(iv) | gradient = (–) (8.0 – 4.8) / (11.6 – 0) (*allow any correct pair of values from Fig. 10.1*) | **C1** |
| | $\lambda = 0.28\ \text{s}^{-1}$ | **A1** |
| 10(b)(v) | half-life $= 0.693 / \lambda$<br><br>$= 0.693 / 0.28$<br><br>$= 2.5$ s | **A1** |
| 10(c) | (for reaction to occur,) energy is released | **B1** |
| | energy release comes from fall in mass so total mass of products must be less (than mass of carbon-15) | **B1** |