Cambridge Assessment International Education

# Cambridge International AS & A Level

**PHYSICS** **9702/41**

Paper 4 A Level Structured Questions **May/June 2021**

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.

Cambridge International is publishing the mark schemes for the May/June 2021 series for most Cambridge IGCSE™, Cambridge International A and AS Level components and some Cambridge O Level components.

This document consists of **18** printed pages.

## Generic Marking Principles

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

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| GENERIC MARKING PRINCIPLE 1:<br><br>Marks must be awarded in line with:<br><br>• the specific content of the mark scheme or the generic level descriptors for the question<br>• the specific skills defined in the mark scheme or in the generic level descriptors for the question<br>• the standard of response required by a candidate as exemplified by the standardisation scripts. |
| GENERIC MARKING PRINCIPLE 2:<br><br>Marks awarded are always **whole marks** (not half marks, or other fractions). |
| GENERIC MARKING PRINCIPLE 3:<br><br>Marks must be awarded **positively**:<br><br>• marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate<br>• marks are awarded when candidates clearly demonstrate what they know and can do<br>• marks are not deducted for errors<br>• marks are not deducted for omissions<br>• answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous. |
| GENERIC MARKING PRINCIPLE 4:<br><br>Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors. |

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| GENERIC MARKING PRINCIPLE 5:<br><br>Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen). |
| GENERIC MARKING PRINCIPLE 6:<br><br>Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind. |

**Science-Specific Marking Principles**

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| 1 | Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly. |
| 2 | The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored. |
| 3 | Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection). |
| 4 | The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted. |

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| 5 | <u>'List rule' guidance</u><br><br>For questions that require ***n*** responses (e.g. State **two** reasons …):<br><br>• The response should be read as continuous prose, even when numbered answer spaces are provided.<br>• Any response marked *ignore* in the mark scheme should not count towards ***n***.<br>• Incorrect responses should not be awarded credit but will still count towards ***n***.<br>• Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response.<br>• Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science. |
| 6 | <u>Calculation specific guidance</u><br><br>Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.<br><br>For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.<br><br>For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient ($a$) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.<br><br>Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme. |
| 7 | <u>Guidance for chemical equations</u><br><br>Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.<br><br>State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme. |

**Abbreviations**

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| / | 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**

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| **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>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**

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| ✓ | 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 $1.6 \times 10^{-19}$ has been written down as $6.1 \times 10^{-19}$ or $1.6 \times 10^{19}$.<br>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. |

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| **^** | 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) | force per unit mass | B1 |
| 1(b) | $GMm / r^2 = mr\omega^2$ **and** $\omega = 2\pi/T$<br>**or**<br>$GMm / r^2 = mv^2 / r$ **and** $v = 2\pi r / T$ | C1 |
| | $6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (94 \times 60)]^2$ | C1 |
| | $r = 6.9 \times 10^6$ m | A1 |
| 1(c)(i) | $r^3\omega^2$ = constant **or** $r^3 / T^2$ = constant | C1 |
| | $r^3 / (6.9 \times 10^6)^3 = (150 / 94)^2$ so $r = 9.4 \times 10^6$ m | A1 |
| | **or** | |
| | $GMT^2/4\pi^2 = r^3$ **and** clear that $M$ is $6.0 \times 10^{24}$ | (C1) |
| | $6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (150 \times 60)]^2$<br>so $r = 9.4 \times 10^6$ m | (A1) |
| 1(c)(ii) | separation increases so (potential energy) increases<br>**or**<br>movement is against gravitational force so (potential energy) increases | B1 |
| 1(c)(iii) | potential energy = (–)$GMm / r$ | C1 |
| | $\Delta E_P = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 1200 \times [(6.9 \times 10^6)^{-1} - (9.4 \times 10^6)^{-1}]$ | C1 |
| | $= 1.9 \times 10^{10}$ J | A1 |

| Question | Answer | Marks |
|---|---|---|
| 2(a) | $pV = NkT$ | C1 |
| | $N = (1.8 \times 10^{-3} \times 3.3 \times 10^{5}) / (1.38 \times 10^{-23} \times 310) = 1.4 \times 10^{23}$ | A1 |
| | **or** | |
| | $pV = nRT$ **and** $nN_A = N$ | (C1) |
| | $N = (1.8 \times 10^{-3} \times 3.3 \times 10^{5} \times 6.02 \times 10^{23}) / (8.31 \times 310) = 1.4 \times 10^{23}$ | (A1) |
| 2(b) | speed of molecule decreases on impact with moving piston | B1 |
| | mean square speed (directly) proportional to (thermodynamic) temperature<br>**or**<br>mean square speed (directly) proportional to kinetic energy (of molecules)<br>**or**<br>kinetic energy (of molecules) (directly) proportional to (thermodynamic) temperature | B1 |
| | kinetic energy (of molecules) decreases (so temperature decreases) | B1 |
| 2(c)(i) | $\Delta U = 3/2 \times k \times \Delta T \times N$ | C1 |
| | $= 3/2 \times 1.38 \times 10^{-23} \times (288 - 310) \times 1.4 \times 10^{23}$ | C1 |
| | $= -64$ J | A1 |
| 2(c)(ii) | decrease in internal energy is less than work done by gas | M1 |
| | (thermal energy is) transferred <u>to</u> the gas (during the expansion) | A1 |

| Question | Answer | Marks |
|---|---|---|
| 3(a) | acceleration (directly) proportional to displacement | **B1** |
| | acceleration is in opposite <u>direction</u> to displacement | **B1** |
| 3(b) | $\omega^2 = 2k / m$ **and** $\omega = 2\pi f$ | **C1** |
| | $(2\pi f)^2 = (2 \times 130) / 0.84$ | **C1** |
| | $f = 2.8$ Hz | **A1** |
| 3(c)(i) | resonance | **B1** |
| 3(c)(ii) | oscillator supplies energy (continuously) | **B1** |
| | energy of trolley constant so energy must be dissipated<br>**or**<br>without loss of energy the amplitude would continuously increase | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 4 | (ultrasound) pulse | **B1** |
| | reflected at boundaries | **B1** |
| | gel is used to minimise reflection at skin<br>**or**<br>generated <u>and</u> detected by quartz crystal | **B1** |
| | time delay between generation and detection gives information about depth | **B1** |
| | intensity (of reflected wave) gives information about nature of boundary | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 5(a) | amplitude of the carrier wave varies | **M1** |
| | in synchrony with the displacement of the (information) signal | **A1** |
| 5(b)(i) | wavelength $= (3.0 \times 10^8) / (300 \times 10^3)$<br>$= 1000$ m | **A1** |
| 5(b)(ii) | bandwidth = 16 kHz | **A1** |
| 5(b)(iii) | frequency = 8 kHz | **A1** |
| 5(c) | attenuation = $10 \lg (P_1 / P_2)$ | **C1** |
| | $73 = 10 \lg (P_T / P_R)$<br>$73 = 10 \lg (P_T x^2 / 0.082 P_T)$ **or** $x^2 / 0.082 = 10^{7.3}$ | **C1** |
| | $x = 1300$ m | **A1** |

| Question | Answer | Marks |
|---|---|---|
| 6(a) | from $x = 0$ to $x = r$: $E = 0$ | **B1** |
| | from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through ($r$, $E_0$) | **B1** |
| | line passing through (2$r$, $E_0$ / 4) and (3$r$, $E_0$ / 9) | **B1** |
| 6(b) | from $p = p_0$ / 2 to $p = p_0$: curve with negative gradient of decreasing magnitude passing through ($p_0$, $\lambda_0$) | **B1** |
| | line passing through (½$p_0$, 2$\lambda_0$) | **B1** |
| 6(c) | from $t$ = 0 to $t$ = 45 s: curve with positive gradient of decreasing magnitude starting at (0, 0) | **B1** |
| | line passing through (15, ½$N_0$) | **B1** |
| | line passing through (30, 0.75$N_0$) and (45, 0.88$N_0$) | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 7(a) | charge / potential | **M1** |
| | charge is on one plate, potential is p.d. between the plates | **A1** |
| 7(b)(i) | $I = Q / t$ | **M1** |
| | charge = *CV* <u>and</u> time = 1 / *f* leading to $I = fCV$ | **A1** |
| 7(b)(ii) | $4.8 \times 10^{-6} = 150 \times 60 \times C$ | **C1** |
| | $C$ = 530 pF | **A1** |
| 7(c) | (total) capacitance is halved | **B1** |
| | charge (for each cycle/discharge) is halved<br>**or**<br>since *f* and *V* are constant, current is proportional to capacitance | **B1** |
| | current = 2.4 μA | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 8(a) | $V^+ = 3.0 \times 3.0 / (2.5 + 3.0)$ | C1 |
| | $= 1.6$ V | A1 |
| 8(b) | $V^-$ is +2.0 V<br>**or**<br>$V^- > V^+$ | B1 |
| | output is negative so (LED) does not emit light | B1 |
| 8(c) | at 0 °C, $V^- = 1.7$ V<br>**or**<br>for all temperatures above 0 °C, resistance of thermistor < 4.2 kΩ | B1 |
| | $V^-$ always greater than $V^+$ (so no switching) | B1 |
| 8(d) | (at 20 °C,) $R_T = 1.8$ kΩ | C1 |
| | $2.5 / 3.0 = 1.8 / R$<br>**or**<br>$[R / (R + 1.8)] \times 3.0 = 1.6$ | C1 |
| | $R = 2.2$ kΩ | A1 |

| Question | Answer | Marks |
|---|---|---|
| 9(a) | region where there is a force exerted on | **M1** |
| | a current-carrying conductor<br>**or**<br>a <u>moving</u> charge<br>**or**<br>a magnetic material/magnetic pole | **A1** |
| 9(b)(i) | face PSWV shaded | **B1** |
| 9(b)(ii) | accumulating electrons cause an electric field (between the faces) | **B1** |
| | force due to electric field opposes force due to magnetic field | **B1** |
| | accumulation stops when magnetic force equals electric force | **B1** |
| 9(c)(i) | number density of charge carriers | **B1** |
| 9(c)(ii) | PV **or** QT **or** SW | **B1** |
| 9(d) | (for semiconductor,) $n$ is (much) smaller so $V_H$ (much) larger | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 10(a) | direction of (induced) e.m.f. | **M1** |
| | is such as to oppose the <u>change</u> causing it | **A1** |
| 10(b) | ring cuts (magnetic) flux and causes induced e.m.f. in ring | **B1** |
| | (induced) e.m.f. causes (eddy/induced) currents (in ring) | **B1** |
| | currents (in ring) cause magnetic field (around ring) | **M1** |
| | two fields interact to cause resistive/opposing force | **A1** |
| | **or** | |
| | current (in ring) is in a magnetic field | **(M1)** |
| | which causes resistive force | **(A1)** |
| | **or** | |
| | currents (in ring) dissipate thermal energy | **(M1)** |
| | (thermal) energy comes from energy of oscillations | **(A1)** |
| 10(c) | current cannot pass all the way around the ring | **B1** |
| | (induced) currents smaller | **B1** |
| | smaller resistive force (so more oscillations)<br>**or**<br>smaller <u>rate</u> of dissipation of energy (so more oscillations) | **B1** |

| Question | Answer | Marks |
|---|---|---|
| 11(a) | intensity: vary filament current/p.d. across filament | B1 |
| | hardness: vary accelerating potential difference | B1 |
| 11(b)(i) | $I = I_0 e^{-\mu x}$ | C1 |
| | $I_S = I_0 \exp(-0.92 \times 9.0)$<br>$= 2.5 \times 10^{-4} I_0$ | A1 |
| 11(b)(ii) | $I_C = [\exp(-0.92 \times 6.0) \times \exp(-2.9 \times 3.0)] I_0$ | C1 |
| | $= 6.7 \times 10^{-7} I_0$ | A1 |
| 11(c) | conclusion consistent with values in **(b)(i)** and **(b)(ii)**<br>e.g. $I_S \gg I_C$ so good contrast | B1 |

| Question | Answer | Marks |
|---|---|---|
| 12(a) | • frequency determines energy of photon<br>• intensity determines number of photons (per unit time)<br>• intensity does not determine energy of a photon<br>*Any two points, 1 mark each* | B2 |
| | kinetic energy (of the electron) depends on the energy of one photon | B1 |
| 12(b)(i) | $E = hc / \lambda$<br>**or**<br>$E = hf$ **and** $c = f\lambda$ | C1 |
| | $E = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (250 \times 10^{-9})$ | C1 |
| | $(= 7.96 \times 10^{-19}$ J)<br>= 5.0 eV | A1 |
| 12(b)(ii) | $E_{MAX}$ = photon energy – work function | C1 |
| | work function = 5.0 – 1.4<br>= 3.6 eV | A1 |