



Cambridge International AS & A Level

PHYSICS

9702/42

Paper 4 A Level Structured Questions

March 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.

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This document consists of **19** printed pages.

PUBLISHED**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.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- 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
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- 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:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

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:

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

- 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.
- 5 'List rule' guidance
 For questions that require *n* responses (e.g. State **two** reasons ...):
 - The response should be read as continuous prose, even when numbered answer spaces are provided.
 - Any response marked *ignore* in the mark scheme should not count towards *n*.
 - Incorrect responses should not be awarded credit but will still count towards *n*.
 - 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.
 - Non-contradictory responses after the first *n* responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

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'.

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.

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.

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 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Examples of how to apply the list ruleState **three** reasons.... [3]

A	1. Correct	✓	2
	2. Correct	✓	
	3. Wrong	x	

B (4 responses)	1. Correct, Correct	✓, ✓	3
	2. Correct	✓	
	3. Wrong	ignore	

C (4 responses)	1. Correct	✓	2
	2. Correct, Wrong	✓, x	
	3. Correct	ignore	

D (4 responses)	1. Correct	✓	2
	2. Correct, CON (of 2.)	x, (discount 2)	
	3. Correct	✓	

E (4 responses)	1. Correct	✓	3
	2. Correct	✓	
	3. Correct, Wrong	✓	

F (4 responses)	1. Correct	✓	2
	2. Correct	✓	
	3. Correct CON (of 3.)	x (discount 3)	

G (5 responses)	1. Correct	✓	3
	2. Correct	✓	
	3. Correct Correct CON (of 4.)	✓ ignore ignore	

H (4 responses)	1. Correct	✓	2
	2. Correct	x	
	3. CON (of 2.) Correct	(discount 2) ✓	

I (4 responses)	1. Correct	✓	2
	2. Correct	x	
	3. Correct CON (of 2.)	✓ (discount 2)	

PUBLISHED**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.

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.

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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)	(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(b)	correct read offs from the graph with correct power of ten for R^3	C1
	$M = \frac{4 \times \pi^2 \times 1.2 \times 10^{34}}{6.67 \times 10^{-11} \times 2.4 \times (365 \times 24 \times 3600)^2}$	C1
	$= 3.0 \times 10^{30} \text{ kg}$	A1
1(c)(i)	potential energy is zero at infinity	B1
	(gravitational) forces are attractive	B1
	work must be done on the rock to move it to infinity	B1
1(c)(ii)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ OR $v^2 = \frac{GM}{r}$ OR $v = \sqrt{\frac{GM}{r}}$	M1
	use of $\frac{1}{2} mv^2$ (e.g. multiplication by $\frac{1}{2} m$) leading to $\frac{GMm}{2r}$	A1
1(c)(iii)	$E_p = \phi m$ <u>and</u> $\phi = \frac{-GM}{r}$ or $E_p = \frac{-GMm}{r}$	C1
	Total energy = $E_k + E_p$ $\text{Total energy} = \frac{GMm}{2r} + \frac{-GMm}{r} = \frac{-GMm}{2r}$	A1

Question	Answer	Marks
2(a)(i)	$pV = NkT$ or $pV = nRT$ <u>and</u> $N = nN_A$ $N = \frac{2.3 \times 10^5 \times 3.5 \times 10^{-3}}{1.38 \times 10^{-23} \times 294}$ $= 2.0 \times 10^{23}$	C1 A1
2(a)(ii)	$pV = \frac{1}{3} Nmc^2$ $c^2 = \frac{3 \times 2.3 \times 10^5 \times 3.5 \times 10^{-3}}{2.0 \times 10^{23} \times 40 \times 1.66 \times 10^{-27}}$ $= 182\,000$ r.m.s. speed = 430 m s ⁻¹ or $\frac{1}{2} mc^2 = \frac{3}{2} kT$ $c^2 = \frac{3 \times 1.38 \times 10^{-23} \times 294}{40 \times 1.66 \times 10^{-27}}$ $= 183\,000$ r.m.s. speed = 430 m s ⁻¹	C1 A1 (C1) (A1)

Question	Answer	Marks
2(b)	$c^2 = \frac{3 \times 2.0 \times 10^{23} \times 1.38 \times 10^{-23} \times (294 + 84)}{2.0 \times 10^{23} \times 40 \times 1.66 \times 10^{-27}}$ $c^2 = 236000$ $c = 485$	C1
	$\text{ratio} \left(= \frac{485}{430} \right) = 1.1$	A1
	OR $v \propto \sqrt{T}$ or $v^2 \propto T$	(C1)
	$\text{ratio} = \sqrt{\frac{273 + 21 + 84}{273 + 21}}$ or $\sqrt{\frac{378}{294}}$ $\text{ratio} = 1.1$	(A1)

Question	Answer	Marks
3(a)	Any 2 from: <ul style="list-style-type: none"> • particles / atoms / molecules / ions (very) close together / touching • regular, repeating pattern • vibrate about a fixed point 	B2
3(b)	(much) greater <u>increase</u> in spacing of molecules (for vaporisation compared with fusion)	B1
3(c)(i)	−100 °C	B1

Question	Answer	Marks
3(c)(ii)	time = $8.5 - 3.0$ = 5.5 min	C1
	$Pt = mL$ energy = power \times time = $150 \times 5.5 \times 60$ = 49 500 J $L = \frac{E}{m}$ $= \frac{49500}{0.045}$	C1
	= 1100 kJ kg ⁻¹	A1
3(c)(iii)	gas has a higher specific heat capacity (than liquid)	B1

Question	Answer	Marks
4(a)	acceleration and displacement are in opposite directions	B1
4(b)(i)	$F = kx$ = $8.0 \times (0.060 - 0.048)$ or $8.0 \times (0.060 + 0.048)$ or 8.0×0.012 or 8.0×0.108	M1
	$\Sigma F = (8.0 \times 0.012) - (8.0 \times 0.108) = 0.77 N$ or $\Sigma F = 0.864 - 0.096 = 0.77 N$	A1

Question	Answer	Marks
4(b)(ii)	$a = \frac{F}{m}$ $= \frac{0.77}{0.25}$ $= 3.1 \text{ms}^{-2}$	A1
4(b)(iii)	$a = -\omega^2 x$ $\omega = \sqrt{\frac{3.1}{0.048}}$ $\omega = 8.04$	C1
	$T = 2\pi / \omega$	C1
	$T = 2\pi / 8.04$ $= 0.78 \text{ s}$	A1
4(b)(iv)	(resultant) force halved and distance halved	B1
	same T	B1

Question	Answer	Marks
5(a)(i)	amplitude of the carrier wave varies	M1
	in synchrony with the displacement of the (information) signal	A1
5(a)(ii)	Any 2 from: <ul style="list-style-type: none"> • fewer transmitters needed / each transmitter can cover a greater distance • more stations can share waveband • transmitters and receivers are cheaper 	B2

Question	Answer	Marks
5(b)(i)	$\lambda = \frac{v}{f}$ $= \frac{3.0 \times 10^8}{1.5 \times 10^6} = 200 \text{ m}$	A1
5(b)(ii)	10 kHz	B1
5(c)	1520 kHz	B1

Question	Answer	Marks
6(a)	(both have) radial field lines	B1
6(b)(i)	2.1 cm	B1
6(b)(ii)	$E = \frac{Q}{4\pi\epsilon_0 r^2}$ <p>e.g. $r = 2.1 \text{ cm}$, $E = 1.30 \times 10^5 \text{ V m}^{-1}$</p> $Q = 4\pi\epsilon_0 r^2 E$ $= 4 \times \pi \times 8.85 \times 10^{-12} \times 0.021^2 \times 1.30 \times 10^5$	C1
	$= 6.4 \times 10^{-9} \text{ C}$	A1

Question	Answer	Marks
6(c)	$C = \frac{Q}{V}$ <p><i>either</i></p> $V = \frac{Q}{4\pi\epsilon_0 r} \text{ leading to } C = 4\pi\epsilon_0 r$	C1
	$C = 4 \times \pi \times 8.85 \times 10^{-12} \times 0.021$	C1
	$(C =) 2.3 \times 10^{-12} \text{ F}$	A1
	<p><i>or</i></p> $V = \frac{Q}{4\pi\epsilon_0 r}$ $= \frac{6.4 \times 10^{-9}}{4 \times \pi \times 8.85 \times 10^{-12} \times 0.021}$ $= 2740 \text{ V}$ $C = \frac{6.4 \times 10^{-9}}{2740}$	(C1)
	$= 2.3 \times 10^{-12} \text{ F}$	(A1)

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Question	Answer	Marks
7(a)(i)	non-inverting (amplifier)	B1
7(a)(ii)	$\text{gain} = \frac{R_f}{R} + 1$ $\text{gain} = \frac{3.6}{0.72} + 1 = 6.0$	B1
7(a)(iii)	straight line from (0,0) to ($T/2$, 3)	B1
	line from origin to 3.0 V then horizontal line at 3.0 V to T	B1
7(a)(iv)	ldr / light dependent resistor replaces one of the two resistors	B1
7(b)(i)	relay coil	B1
7(b)(ii)	relay coil between op-amp and earth	B1
	diode with correct polarity (pointing away from output) connected between output and device and no other connections or diode with correct polarity (pointing towards earth) between device and earth and no other connections	B1
	switch connected to high voltage circuit	B1

Question	Answer	Marks
8(a)(i)	at least one anticlockwise arrow and no clockwise arrows	B1
8(a)(ii)	(force is to the) left	B1
8(a)(iii)	force is the same	B1
	Newton's third law (of motion) or force depends on the product of the two currents	B1

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Question	Answer	Marks
8(b)(i)	frequency of radio waves is equal to natural frequency of protons	B1
	resonance of protons occurs / protons absorb energy	B1
8(b)(ii)	in between pulses / when pulse stops	B1
	Any 1 from: <ul style="list-style-type: none"> • protons de-excite • protons emit r.f. pulses • emitted (r.f.) pulse (from proton) detected 	B1

Question	Answer	Marks
9(a)	(magnetic) flux density \times area \times number of turns	M1
	area is perpendicular to (magnetic) field	A1
9(b)	use of $t = 1.2$ s	C1
	$\varepsilon = \frac{\Delta BAN}{\Delta t}$ $= \frac{0.250 \times \pi \times 0.030^2 \times 540}{1.2}$	C1
	= 0.32V	A1
9(c)(i)	light damping	B1

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Question	Answer	Marks
9(c)(ii)	sheet cuts (magnetic) flux and causes induced emf	B1
	(induced) emf causes (eddy) currents (in sheet)	B1
	either currents (in sheet) cause resistive force or currents (in sheet) dissipate energy	B1
	smaller currents in Y or larger currents in X, so dashed line is X	B1

Question	Answer	Marks
10(a)	230 V	A1
10(b)	$\omega = 100\pi$	C1
	$T = \frac{2\pi}{\omega} = \frac{2\pi}{100\pi}$ $= 0.020 \text{ s}$	
10(c)(i)	half-wave (rectification)	B1
10(c)(ii)	sinusoidal half waves in positive V only or negative V only, peak at 320 V	B1
	line at zero for second half of cycle	B1
	two time periods shown, each of 0.020 s	B1
10(c)(iii)	capacitor added in parallel with resistor	B1

Question	Answer	Marks
11(a)(i)	electrons decelerate (on hitting target) so X-ray photons produced	B1
	range of decelerations	B1
	photon energy depends on (magnitude of) deceleration	B1
11(a)(ii)	$eV = \frac{hc}{\lambda}$	C1
	$\lambda = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{1.6 \times 10^{-19} \times 15000}$	C1
	$= 8.3 \times 10^{-11} m$	A1
	or $E = hf$ <u>and</u> $c = f\lambda$ <u>and</u> electron energy = eV or $E = hc / \lambda$ <u>and</u> electron energy = eV electron energy = $1.6 \times 10^{-19} \times 15000$ $= 2.4 \times 10^{-15}$	(C1)
	$\lambda = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{2.4 \times 10^{-15}}$	(C1)
	$\lambda = 8.3 \times 10^{-11} m$	(A1)
	11(b)(i)	$\mu = -\text{gradient}$ <u>or</u> $\ln(I/I_0) = -\mu x$
	(e.g. $2.08 / 10.0$) = 0.21 cm^{-1}	A1

Question	Answer	Marks
11(b)(ii)	$\ln(0.05) = -\mu x$	C1
	$x = \frac{\ln 0.05}{-\mu}$ <i>e.g. x = 14 cm</i>	A1

Question	Answer	Marks
12(a)	1 not affected by external factors	B1
	2 cannot predict when a (particular) nucleus will decay <i>or</i> cannot predict which nucleus will decay (next)	B1
12(b)(i)	Number of atoms = $\frac{1.0 \times 10^{-9}}{90 \times 1.66 \times 10^{-27}}$ <i>or</i> $\frac{1.0 \times 10^{-9} \times 6.02 \times 10^{23}}{90 \times 10^{-3}}$ $= 6.693 \times 10^{15}$	C1
	$A = \lambda N$ $\lambda = \frac{5.2 \times 10^6}{6.693 \times 10^{15}}$	C1
	$\lambda = 7.8 \times 10^{-10} \text{ s}^{-1}$	A1
12(b)(ii)	daughter nucleus is unstable	B1