



Cambridge International AS & A Level

PHYSICS

9702/41

Paper 4 A Level Structured Questions

October/November 2020

MARK SCHEME

Maximum Mark: 100

<p>Published</p>

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

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.

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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 1.6×10^{-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.
MO	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.

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Question	Answer	Marks
1(a)(i)	region (of space)	B1
	where a particle experiences a force	B1
1(a)(ii)	force per unit mass	B1
1(b)	$g = GM / R^2$	C1
	$= (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (3.39 \times 10^6)^2$	C1
	$= 3.73 \text{ N kg}^{-1}$	A1

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Question	Answer	Marks
1(c)	$0.99 \times 3.73 = (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / r^2$	C1
	$r = 3.41 \times 10^6 \text{ (m)}$	C1
	height = $(r - R)$ $= 2 \times 10^4 \text{ m}$	A1
	or	
	$0.99 \times 3.73 = (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (R + h)^2$ $(R + h)^2 = 1.1596 \times 10^{13}$	(C1)
	$R + h = 3.41 \times 10^6 \text{ (m)}$	(C1)
	$h = 2 \times 10^4 \text{ m}$	(A1)
	or	
	$0.99 = (3.39 \times 10^6)^2 / r^2$	(C1)
	$r = 3.41 \times 10^6 \text{ (m)}$	(C1)
	height = $2 \times 10^4 \text{ m}$	(A1)

Question	Answer	Marks															
2(a)	+ q : thermal energy transfer to system	B1															
	+ w : work done on system	B1															
2(b)(i)	($W =$) $2.6 \times 10^5 \times (3.8 - 2.3) \times 10^{-3} = 390 \text{ J}$	A1															
2(b)(ii)	no (total) change (in internal energy)	B1															
	gas returns to its original temperature	B1															
2(c)	A to B row all correct (1370, – 390, 980)	B1															
	B to C row all correct (0, 550, 550)	B1															
	C to A row: ΔU adds to the other two ΔU values to give zero	B1															
	C to A row: $w = 0$ and q adds to w to give ΔU value	B1															
	complete correct answer:																
	<table><tr><td>change</td><td>q / J</td><td>w / J</td><td>$\Delta U / \text{J}$</td></tr><tr><td>A to B</td><td>(+)1370</td><td>–390</td><td>(+)980</td></tr><tr><td>B to C</td><td>0</td><td>(+)550</td><td>(+)550</td></tr><tr><td>C to A</td><td>–1530</td><td>0</td><td>–1530</td></tr></table>	change	q / J	w / J	$\Delta U / \text{J}$	A to B	(+)1370	–390	(+)980	B to C	0	(+)550	(+)550	C to A	–1530	0	–1530
change	q / J	w / J	$\Delta U / \text{J}$														
A to B	(+)1370	–390	(+)980														
B to C	0	(+)550	(+)550														
C to A	–1530	0	–1530														

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Question	Answer	Marks
3(a)	acceleration (directly) proportional to displacement	B1
	acceleration in opposite <u>direction</u> to displacement or acceleration (directed) towards equilibrium position	B1
3(b)	$v = \omega(x_0^2 - x^2)^{1/2}$ and $\omega = 2\pi f$ or $v_0 = x_0\omega$ and $\omega = 2\pi f$	C1
	substitution of any correct point from graph, e.g. for $x = 0$: $0.25 = 2\pi f \times 8.8 \times 10^{-2}$	C1
	$f = 0.45 \text{ Hz}$	A1
3(c)	$1 / 0.45 = 2\pi \times (L / 9.81)^{1/2}$	C1
	$L = 1.2 \text{ m}$	A1
3(d)	ellipse about the origin with same intercepts on x-axis	B1
	ellipse about the origin crossing v-axis inside original loop	B1

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Question	Answer	Marks
4(a)	quartz crystal	B1
	alternating p.d. across crystal causes it to vibrate	B1
	resonance occurs when frequency of p.d. matches natural frequency of crystal	B1
	natural frequency of crystal is in ultrasound range	B1
4(b)	$I = I_0 e^{-\mu x}$	C1
	$I / I_0 = e^{-1.2 \times 3.5}$ $= 0.015$	C1
	ratio / dB = $-10 \lg (1 / 0.015)$ or $10 \lg (0.015)$	C1
	$= -18 \text{ dB}$	A1

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Question	Answer	Marks
5(a)	work done per unit charge	B1
	(work done on charge) moving positive charge from infinity	B1
5(b)(i)	$(2.0 \times 10^{-9}) / 4\pi\epsilon_0(4.0 \times 10^{-2}) + Q / 4\pi\epsilon_0(8.0 \times 10^{-2}) = 0$	C1
	$Q = 4.0 \times 10^{-9} \text{ C}$	A1
	Q given with negative sign	B1
5(b)(ii)	change = 1200 V	A1
5(c)	$\frac{1}{2}mv^2 = qV$	C1
	$\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 1200$	C1
	$v = 3.4 \times 10^5 \text{ m s}^{-1}$	A1

Question	Answer	Marks
6(a)(i)	charge per unit potential (difference)	M1
	charge on one plate <u>and</u> potential difference across the plates	A1
6(a)(ii)	any three points from: <ul style="list-style-type: none"> • smoothing • timing/(time) delay • tuning • oscillator • blocking d.c. • surge protection • temporary power supply 	B3
6(b)	(capacitors in series have combined capacitance =) $8\ \mu\text{F}$	C1
	capacitance = $8 + 24$ $= 32\ \mu\text{F}$	A1

Question	Answer	Marks
7(a)	two resistors connected in series between earth and positive of battery and no extra connections	B1
	one resistor and thermistor connected in series between earth and positive of battery and no extra connections	B1
	midpoints of the two potential dividers connected, one each, to the op-amp input terminals	B1
	thermistor in correct place in potential divider circuit (either the upper part of the potential divider leading to V^+ or the lower part of the potential divider leading to V^-)	B1
7(b)(i)	value greater than $1000\ \Omega$	A1
7(b)(ii)	non-zero value less than $1000\ \Omega$	A1

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Question	Answer	Marks
8(a)(i)	downwards	B1
8(a)(ii)	PQRS and JKLM	B1
8(b)	(as charge separates) an electric field is created (between opposite faces)	B1
	(maximum value is reached when) electric force (on electron) is equal and opposite to magnetic force (on electron)	B1
8(c)	$V_H = BI / ntq$ $= (4.6 \times 10^{-3} \times 6.3 \times 10^{-4}) / (1.3 \times 10^{29} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1
	$= 1.4 \times 10^{-12} \text{ V}$	A1
8(d)	semiconductors have a (much) smaller value for n	B1
	V_H for semiconductors is (much) larger so more easily measured	B1

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Question	Answer	Marks
9(a)	flux density \times area	M1
	where flux is normal to area	A1
	or	
	flux density \times area $\times \sin \theta$	(M1)
	where θ is angle between flux direction and (plane of) area	(A1)
9(b)(i)	(alternating) current creates changing (magnetic) flux	B1
	core links (magnetic) flux with secondary coil	B1
	changing flux (in secondary) causes induced e.m.f.	B1
9(b)(ii)	rate of change of flux is not constant	B1
	(induced) e.m.f. is proportional to rate of change of flux	B1
9(c)	reduces induced currents in core	B1
	hence reduces energy losses (in core)	B1

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Question	Answer	Marks
10(a)	X-rays are used	B1
	section (of object) is scanned	B1
	scans/images taken at many angles/directions or images of each section are 2-dimensional	B1
	(images of (many)) sections are combined	B1
	(to give) 3-dimensional image of (whole) structure	B1
10(b)	K = 6 L = 7 M = 2 N = 9 3 marks: all four correct 2 marks: three correct and one incorrect or all correct with two numbers transposed 1 mark: two correct and two incorrect	B3

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Question	Answer	Marks
11(a)(i)	quantum of energy	M1
	of electromagnetic radiation	A1
11(a)(ii)	arrow (on Fig. 11.1) pointing upwards and to the right	B1
11(b)(i)	$\lambda = h / p$	C1
	$p = (6.63 \times 10^{-34}) / (544 \times 10^{-9})$	A1
	$= 1.22 \times 10^{-27} \text{ N s}$	
11(b)(ii)	energy = hc / λ	C1
	$= 6.63 \times 10^{-34} \times 3.00 \times 10^8 \times (540^{-1} - 544^{-1}) \times 10^9$	A1
	$= 2.7 \times 10^{-21} \text{ J}$	
11(c)	(smaller wavelength corresponds to) greater photon energy	B1
	any one point from: <ul style="list-style-type: none"> • (deflected) photon loses energy (so not possible) • (deflected) photon would need to gain energy (so not possible) • electron would need to lose energy (so not possible) • initially electron energy is zero (so not possible) 	B1

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Question	Answer	Marks
12(a)(i)	unstable nucleus	B1
	emits ionising radiation or decays spontaneously	B1
12(a)(ii)	probability of decay (of a nucleus)	M1
	per unit time	A1
12(b)	$A = \lambda N$	C1
	$560 = 9.9 \times 10^{-7} \times N$	A1
	$N = 5.7 \times 10^8$	
12(c)	$A = A_0 e^{-\lambda t}$	C1
	$170 = 560 \exp(-9.9 \times 10^{-7} \times t)$	
	$t = 1.2 \times 10^6 \text{ s}$	C1
	= 14 days	A1