Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **October/November 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 **15** 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.

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.
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)	constant speed **or** constant magnitude of velocity	**B1**
	acceleration (always) perpendicular to velocity	**B1**
1(b)(i)	$F = mv^2 / r$ **or** $v = r\omega$ **and** $F = mr\omega^2$	**C1**
	$F = 790 \times 94^2 / 318$ $= 22\,000$ N	**A1**
1(b)(ii)	centripetal acceleration: same	**B1**
	maximum speed: greater	**B1**
	time taken for one lap of the track: greater	**B1**

Question	Answer	Marks
2(a)	work done per unit mass	**B1**
	(work done in) moving mass from infinity	**B1**
2(b)(i)	(gravitational) fields from the Earth and Moon are in opposite directions	**B1**
	(resultant is zero where gravitational) fields are equal (in magnitude)	**B1**
2(b)(ii)	$g \propto M / r^2$	**C1**
	$5.98 \times 10^{24} / x^2 = 7.35 \times 10^{22} / (3.84 \times 10^8 - x)^2$ leading to $x = 3.5 \times 10^8$ (m)	**A1**
2(b)(iii)	ϕ (Earth) = (–)$6.67 \times 10^{-11} \times (5.98 \times 10^{24} / 3.5 \times 10^8)$ **and** ϕ (Moon) = (–)$6.67 \times 10^{-11} \times (7.35 \times 10^{22} / 0.38 \times 10^8)$	**C1**
	ϕ = (–)$6.67 \times 10^{-11} \times [(5.98 \times 10^{24} / 3.5 \times 10^8) + (7.35 \times 10^{22} / 0.38 \times 10^8)]$	**C1**
	$= -1.3 \times 10^6$ J kg^{-1}	**A1**

Question	Answer	Marks
3(a)	(thermal) energy per unit mass (to cause temperature change)	**B1**
	(thermal) energy per unit <u>change</u> in temperature	**B1**
3(b)(i)	(T =) pV / Nk	**B1**
3(b)(ii)	(pV =) $NkT = ⅓Nm<c^2>$ **or** $pV = NkT$ **and** $pV = ⅓Nm<c^2>$	**M1**
	leading to $½m<c^2> = (3/2)kT$ and $½m<c^2> = E_K$	**A1**
3(b)(iii)	internal energy = ΣE_K (of molecules) + ΣE_P (of molecules) **or** no forces between molecules	**B1**
	potential energy of molecules is zero	**B1**
3(c)(i)	increase in internal energy = Q + work done	**B1**
	constant volume so no work done	**B1**
3(c)(ii)	$c = Q / Nm\Delta T$	**C1**
	$= [N \times (3/2)k\Delta T] / (Nm\Delta T) = 3k / 2m$	**A1**
3(d)	(as it expands) gas does work (against the atmosphere/external pressure)	**B1**
	for same temperature rise) more (thermal) energy needed, so larger specific heat capacity	**B1**

Question	Answer	Marks
4(a)(i)	5.0 cm	**A1**
4(a)(ii)	$\omega = 2\pi / T$ **or** $\omega = 2\pi f$ **and** $f = 1 / T$	**C1**
	$\omega = 2\pi / 4.0$ $= 1.6 \text{ rad s}^{-1}$	**A1**
4(a)(iii)	$v_0 = \omega x_0$	**C1**
	$= 1.57 \times 5.0$ $= 7.9 \text{ cm s}^{-1}$	**A1**
4(b)	• initial pull was to the right • distance from X to trolley (at equilibrium) is 20 cm • period is 4.0 s • initial motion undamped • motion becomes damped at/from 12 s • damping is light • maximum speed at 1 s, 3 s, etc. / stationary at 2 s, 4 s, etc. *Any three points, 1 mark each*	**B3**
4(c)	sketch: closed loop encircling (20, 0)	**B1**
	minimum *L* shown as 15 cm <u>and</u> maximum *L* shown as 25 cm	**B1**
	minimum *v* shown as -7.9 cm s^{-1} <u>and</u> maximum *v* shown as $+7.9 \text{ cm s}^{-1}$	**B1**

Question	Answer	Marks
5(a)	• noise can be removed/signal can be regenerated • extra bits can be added for error-checking • signal can be encrypted (for increased security) • data compression/multiplexing is possible *Any two points, 1 mark each*	**B2**
5(b)(i)	4 ms: 0101 **and** 8 ms: 0100	**B1**
5(b)(ii)	sketch: horizontal line continues to 8 ms, then new horizontal line from 8 ms to 12 ms	**B1**
	level of line after 8 ms is 4 mV	**B1**
5(c)	sketch: series of steps of width 2 ms	**B1**
	step heights at 0, 2, 4, 6, 4, 6 mV *2 marks if all correct, 1 mark if only one incorrect*	**B2**

Question	Answer	Marks
6(a)	$Q = CV$ **and** $E = ½CV^2$	**B1**
6(b)(i)	$C_N = CL / (L – D)$	**B1**
6(b)(ii)	(charge is unchanged by moving the plates so) $Q_N = CV$	**B1**
6(b)(iii)	$V_N = Q_N / C_N$ $= (CV) / [CL / (L – D)]$ $= V(L – D) / L$	**B1**
6(c)	oppositely charged plates attract, so energy stored decreases	**B1**

Question	Answer	Marks
7(a)	• infinite (open-loop) gain • infinite slew rate • infinite input impedance • zero output impedance • infinite bandwidth *Any two points, 1 mark each*	**B2**
7(b)	X: thermistor **and** Y: relay	**B1**
7(c)(i)	(any) difference in voltage at the inputs causes output to saturate (because gain is very large)	**B1**
	saturates positively if $V^+ > V^-$ <u>and</u> saturates negatively if $V^+ < V^-$	**B1**
7(c)(ii)	comparator	**B1**
7(c)(iii)	temperature	**M1**
	above a particular value	**A1**
7(c)(iv)	to adjust the temperature (at which the lamp illuminates/extinguishes)	**B1**

Question	Answer	Marks
8(a)	newton per ampere per metre	**M1**
	where current/wire is perpendicular to magnetic field	**A1**
8(b)(i)	$F = BIL\sin\theta$	**C1**
	$B = 1.0 / (5.0 \times 0.060 \times \sin 50°)$ $= 4.4$ mT	**A1**
8(b)(ii)	(from Fleming's left-hand rule) force on wire is upwards, so reading decreases	**B1**
8(b)(iii)	frame will rotate (so that PQ becomes perpendicular to the field)	**B1**

Question	Answer	Marks
9(a)	constant voltage	**M1**
	that produces/dissipates same power as (the mean power of) the alternating voltage	**A1**
9(b)(i)	(maximum) rate of cutting of (magnetic) flux doubles	**B1**
	(peak and hence) r.m.s. induced e.m.f. doubles	**B1**
9(b)(ii)	sketch: (sinusoidal) wave of period 10 ms	**B1**
	peak E shown as ± 34 V (*1 mark out of 2 awarded if peak E shown as* ± 17 V *or* ± 24 V)	**B2**
9(c)	current in the coil results in forces that oppose its rotation **or** current in the resistor dissipates the energy of rotation	**B1**
	coil stops rotating	**B1**

Question	Answer	Marks
10(a)(i)	photoelectric effect	**B1**
10(a)(ii)	electron diffraction	**B1**
10(b)(i)	$\lambda = h / p$	**M1**
	h is the Planck constant	**A1**
10(b)(ii)	de Broglie (wavelength)	**B1**
10(c)(i)	$½mv^2 = eV$	**C1**
	$½ \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 4800$ <u>so</u> $v = 4.1 \times 10^7$ m s^{-1}	**A1**
10(c)(ii)	$\lambda = h / mv$ $= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.1 \times 10^7)$	**C1**
	$= 1.8 \times 10^{-11}$ m	**A1**

Question	Answer	Marks
11(a)(i)	ease with which edges can be distinguished	**B1**
11(a)(ii)	difference in degrees of blackening	**B1**
11(b)	$I = I_0 \exp(-\mu x)$	**C1**
	$0.12 = \exp(-\mu \times 2.3)$ $\ln 0.12 = -2.3 \times \mu$	**C1**
	$\mu = 0.92\ \text{cm}^{-1}$	**A1**
11(c)	advantage: produces 3-dimensional image	**B1**
	disadvantage: (much) greater exposure to radiation	**B1**

Question	Answer	Marks
12(a)	probability of decay (of a nucleus)	**M1**
	per unit time	**A1**
12(b)	$A = \lambda N$	**C1**
	N = mass / (nucleon number × u)	**C1**
	$2.92 \times 10^9 = (\lambda \times 5.87 \times 10^{-10}) / (131 \times 1.66 \times 10^{-27})$ $\lambda = 1.08 \times 10^{-6}\ \text{s}^{-1}$	**A1**
12(c)	• sample emits radiation in all directions • some radiation is absorbed by air/detector window • self-absorption within the source • dead time/inefficiency of detector *Any two points, 1 mark each*	**B2**