Physics Paper 4

Cambridge International AS & A Level

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PHYSICS **9702/42**

Paper 4 A Level Structured Questions **March 2017**

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.

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Question	Answer	Marks
1(a)	work done per unit mass	**M1**
	bringing (small test) mass from infinity (to the point)	**A1**
1(b)(i)	$\Delta\phi = (GM/2R) - (GM/5R) = 3GM/10R$	**A1**
1(b)(ii)	change in GPE = $(3 \times 4.0 \times 10^{14} / 10R) \times 4.7 \times 10^{4}$	**C1**
	$(3 \times 4.0 \times 10^{14} / 10R) \times 4.7 \times 10^{4} = (1.70 - 0.88) \times 10^{12}$ $R = 6.88 \times 10^{6}$	**C1**
	distance $= 3 \times 6.88 \times 10^{6}$ $= 2.1 \times 10^{7}$ m	**A1**

Question	Answer	Marks
2(a)	$+\Delta U$ <u>increase</u> in internal energy $+q$ heat (energy) transferred <u>to</u> the system / heating of system $+w$ work done <u>on</u> system	**B2**
2(b)(i)	$W = p\Delta V$ $= 5.2 \times 10^{5} \times (5.0 - 1.6) \times 10^{-4}$ (=177 J)	**B1**
	$\Delta U = q + w$ $= 442 - 177 = 265$ J	**A1**
2(b)(ii)	no (molecular) potential energy	**B1**
	internal energy decreases so (total molecular) kinetic energy decreases	**B1**
	(mean molecular) kinetic energy decreases so temperature decreases	**B1**

Question	Answer	Marks
2(b)(iii)	$\Delta U + 265 - 313 = 0$ $\Delta U = 48\,\text{J}$	**A1**
2(b)(iv)	$pV = NkT$ or $pV = nRT$ <u>and</u> $N = nN_A$	**C1**
	$5.2 \times 10^5 \times 1.6 \times 10^{-4} = N \times 1.38 \times 10^{-23} \times (273 + 227)$ *or* $5.2 \times 10^5 \times 1.6 \times 10^{-4} = n \times 8.31 \times (273 + 227)$ and $n = N / 6.02 \times 10^{23}$ $N = 1.2 \times 10^{22}$	**A1**

Question	Answer	Marks
3(a)	m is constant *or* k/m is constant <u>and</u> so acceleration / a proportional to displacement / x	**B1**
	negative sign shows that acceleration / a is in opposite direction to displacement / x *or* negative sign shows acceleration / a is towards fixed point	**B1**
3(b)	evidence of comparison to expression to $a = -\omega^2 x$	**B1**
	$\omega^2 = k/m$ *or* $\omega^2 = 4.0/m$ hence $\omega = 2.0/\sqrt{m}$	**A1**
3(c)	$E_K = ½ m \omega^2 x_0^2$ *or* $E_K = ½mv^2$ <u>and</u> $v = \omega x_0$	**C1**
	$= ½m\,(4.0/m)\,(3.0 \times 10^{-2})^2$	**C1**
	$= 1.8 \times 10^{-3}\,\text{J}$	**A1**

Question	Answer	Marks
3(d)	new $x_0 = \sqrt{[(1.8 \times 10^{-3} / 2) \times (2 / m \times (m / 4.0))]}$ *or* ($E_K \propto x_0^2$ so) new $x_0 = \sqrt{[½ \times (3.0 \times 10^{-2})^2]}$	**C1**
	$= 2.12 \times 10^{-2}$ m	**A1**
3(e)	flux linked to block changes / flux is cut by block which induces an e.m.f. in block	**B1**
	(eddy) currents induced in block cause heating	**B1**
	thermal / heat energy comes from (kinetic / potential) energy of oscillations / block	**B1**

Question	Answer	Marks
4	piezo-electric / quartz crystal / transducer	**B1**
	<u>alternating</u> p.d. applied across crystal / transducer	**B1**
	causes crystal to vibrate / resonate	**B1**
	crystal resonates at ultrasound frequencies / crystal's natural frequency is in the ultrasound range / alternating p.d. is in ultrasound frequency range	**B1**

Question	Answer	Marks
5(a)	any **three** from: • greater bandwidth • does not suffer from (e.m.) interference / can be used in (e.m.) 'noisy' environments • no / less power / energy radiated / better security / less cross-talk • less attenuation / fewer repeaters / amplifiers needed • less weight / easier to handle / cheaper / occupy less space	**B3**
5(b)(i)	attenuation / gain = 10 log P_1 / P_2	**C1**
	$0.50 \times 57 = 10 \log (15 \times 10^{-3}/P)$ so $P = 2.1 \times 10^{-5}$ W *or* $-(0.50 \times 57) = 10 \log (P/15 \times 10^{-3})$ so $P = 2.1 \times 10^{-5}$ W	**A1**
5(b)(ii)	*either*	
	(calculation of S / N ratio at receiver) S / N ratio = $10 \log (2.1 \times 10^{-5} / 9.0 \times 10^{-7})$ or S/N ratio = 14	**M1**
	14 < 24 or S/N ratio < minimum S/N ratio	**A1**
	so not able to distinguish signal from noise	**A1**
	or	
	(calculation of minimum acceptable power at receiver) $24 = 10 \log (P / 9.0 \times 10^{-7})$ or $P = 2.3 \times 10^{-4}$	**(M1)**
	$2.1 \times 10^{-5} < 2.3 \times 10^{-4}$ or power < minimum power	**(A1)**
	so not able to distinguish signal from noise	**(A1)**

Question	Answer	Marks
6(a)	similarity: lines are radial / greater separation of lines with increased distance from the sphere	B1
	difference: gravitational lines directed towards sphere <u>and</u> electric lines directed away from sphere	B1
6(b)(i)	$E = Q / 4\pi\varepsilon_0 r^2$ or $E = kQ / r^2$ with k defined / substituted in	C1
	$4.1 \times 10^{-5} = [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.025^2)] - [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.075^2)]$	C1
	$Q = 3.2 \times 10^{-18}$ C	A1
6(b)(ii)	smooth curve with gradient decreasing starting at $(0, 4.1 \times 10^{-5})$ to d-axis at (2.5, 0)	B1
	smooth curve with gradient increasing from (2.5, 0) ending at $(5, -4.1 \times 10^{-5})$	B1
6(b)(iii)	acceleration decreases (to zero at mid-point)	B1
	then acceleration increases in the opposite direction / increasing negative acceleration	B1

Question	Answer	Marks
7(a)	correct grid shape (of wire)	B1
	fine wire / foil strip	B1
	plastic / insulating envelope containing the wire	B1
7(b)(i)	$2.00 / 6.00 = 153.0 / (R + 153.0)$ *or* $4.00 / 6.00 = R / (R + 153.0)$ (so $R = 306.0$)	C1
	$\Delta R = 306.0 - 300.0 = 6.0$ (Ω)	C1
	so $\Delta L = 8(.0) \times 10^{-5}$ m	A1

Question	Answer	Marks
7(b)(ii)	R or ΔR increases	B1
	$V^+ < V^-$ or $V_A < 2.00$ or V^+ / V_A decreases	M1
	output is negative / –5 V	A1
	diode X emits light / is 'on'	A1

Question	Answer	Marks
8(a)	region (of space) where there is a force	M1
	produced by / on a magnet / magnetic pole / <u>moving</u> charge / current-carrying conductor	A1
8(b)(i)	out of (the plane of) the paper / page	B1
8(b)(ii)	the force on the particle is (always) perpendicular to the velocity / perpendicular to the direction of travel / towards the centre of path	B1
	no work is done by the force on the particle / there is no acceleration in the direction of the velocity / the acceleration is (always) perpendicular to the velocity	B1
8(b)(iii)	$F = Bqv$ or $F = mv^2/r$	C1
	$mv^2/(d/2) = Bqv$ so $d = 2mv / Bq$	A1
8(b)(iv)	time = distance / speed $T_{(F)} = \pi d / 2v$	C1
	$T_{(F)} = (\pi / 2v) \times (2mv / Bq)$ $T_{(F)} = \pi m / Bq$ and so $T_{(F)}$ independent of v	A1

Question	Answer	Marks
9(a)(i)	increase flux linkage (with secondary coil) / to reduce flux loss	**B1**
9(a)(ii)	e.m.f. (induced only) when flux (in core/coil) is changing	**B1**
	constant / direct voltage gives constant flux / field	**B1**
9(b)(i)	N_S / N_P = V_S / V_P	**C1**
	N_S = (52 / 150) × 1200 = 416 turns	**A1**
9(b)(ii)	0 ms or 7.5 ms or 15.0 ms or 22.5 ms	**A1**
9(c)(i)	*either*	
	mean power = $V^2 / 2R$ and V = 52 (V)	**C1**
	R = $52^2 / (2 \times 1.2)$ = 1100 (1127) Ω	**A1**
	or	
	mean power = V^2 / R and $V = 52 / \sqrt{2}$ (= 36.8 V)	**(C1)**
	R = $36.8^2 / 1.2$ = 1100 Ω	**(A1)**
9(c)(ii)	sinusoidal shape with troughs at zero power	**B1**
	only 3 ‘cycles’	**B1**
	each ‘cycle’ is 2.4 W high and zero power at correct times	**B1**

Question	Answer	Marks
10(a)	packet / quantum of energy	**M1**
	of electromagnetic radiation	**A1**
10(b)(i)	light is re-emitted in all directions / only part of the re-emitted light is in the direction of the beam	**B1**
10(b)(ii)	an arrow between –3.40 eV and –1.51 eV <u>and</u> an arrow between –3.40 eV and –0.85 eV	**B1**
	all arrows shown point 'upwards'	**B1**
10(b)(iii)	$E = hc / \lambda$ *or* $E = hf$ <u>and</u> $c = f\lambda$	**C1**
	$2.60 \times 1.60 \times 10^{-19} = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda$	**C1**
	$\lambda = 4.8 \times 10^{-7}$ m	**A1**

Question	Answer	Marks
11	any **five** from: • electrons need energy to enter conduction band (from valence band) • (positively-charged) holes are left in valence band • moving charge carriers / holes / electrons are current • (increase of temperature leads to) more (positive and negative) charge carriers / more holes / more electrons so more current • more charge carriers / holes / electrons gives rise to less resistance • (increase of temperature causes) greater (amplitude of) vibrations of atoms / ions / lattice • effect of more charge carriers/holes/electrons is greater than effect of greater vibrations (and so resistance decreases)	**B5**

Question	Answer	Marks
12(a)	*either*	
	(minimum) energy required / work done to separate the nucleons (in a nucleus)	**M1**
	to infinity	**A1**
	or	
	energy released when nucleons come together (to form a nucleus)	**(M1)**
	from infinity	**(A1)**
12(b)(i)	(total) binding energy of thorium and helium (nuclei) greater than binding energy of uranium (nucleus)	**B1**
12(b)(ii)1	change in mass $= 238.05076 - (234.04357 + 4.00260)$ $= 4.59 \times 10^{-3}$ u	**A1**
12(b)(ii)2	*either*	
	$E = mc^2$ $= 4.59 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.00 \times 10^{8})^2$	**C1**
	$= 6.9 \times 10^{-13}$ J	**A1**
	or	
	1u = 931 MeV $E = 4.59 \times 10^{-3} \times 931 \times 10^{6} \times 1.6 \times 10^{-19}$	**(C1)**
	$= 6.8 \times 10^{-13}$ J	**(A1)**
12(b)(iii)	Th nucleus / He nucleus / product nucleus has kinetic energy	**M1**
	energy of gamma photon must be less than energy released	**A1**

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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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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.

Question	Answer	Marks
1(a)	work done per unit mass	**B1**
	work (done on mass) moving mass from infinity (to the point)	**B1**
1(b)(i)	$-3.55 \times 10^7\ \mathrm{J\,kg^{-1}}$	**B1**
1(b)(ii)	$\phi = -\dfrac{GM}{r}$ $M = -\dfrac{-3.55\times10^7\times4\,800\,000}{6.67\times10^{-11}}$ $= 2.55 \times 10^{24}\ \mathrm{kg}$	**B1**
1(b)(iii)	$g = \dfrac{GM}{r^2}$ **or** $g = -\dfrac{\phi}{r}$	**C1**
	$= \dfrac{6.67\times10^{-11}\times2.55\times10^{24}}{4\,800\,000^2}$ **or** $= \dfrac{3.55\times10^7}{4\,800\,000}$ $= 7.4\ \mathrm{N\,kg^{-1}}$	**A1**
1(b)(iv)	r in range 2.60×10^7 to $2.65 \times 10^7\ \mathrm{m}$	**C1**
	$\dfrac{mv^2}{r} = \dfrac{GMm}{r^2}$ **and** $v = \dfrac{2\pi r}{T}$ **or** $mr\omega^2 = \dfrac{GMm}{r^2}$ **and** $\omega = \dfrac{2\pi}{T}$	**C1**
	$T^2 = \dfrac{4\pi^2 r^3}{GM} = \dfrac{4\pi^2\times\left(2.65\times10^7\right)^3}{6.67\times10^{-11}\times2.55\times10^{24}} = 4.20 \times 10^9$	**C1**
	$T = 64\,800\ \mathrm{s}$ $= 18$ hours	**A1**

Question	Answer	Marks
1(c)	similarity – any one point from • inversely proportional to distance (from point) • points of equal potential lie on concentric spheres • zero at infinite distance	**B1**
	difference – any one point from • gravitational potential is (always) negative • electric potential can be positive or negative	**B1**

Question	Answer	Marks
2(a)	gas for which $pV \propto T$	**M1**
	where T is thermodynamic temperature	**A1**
2(b)(i)	evidence of two temperature conversions between °C and K	**B1**
	two calculations shown, one for each state e.g. $\frac{1.10 \times 10^5 \times 540 \times 10^{-6}}{(273 + 27)} = 0.198$ **and** $\frac{6.70 \times 10^6 \times 30 \times 10^{-6}}{(273 + 742)} = 0.198$	**A1**
2(b)(ii)	work is done on the gas	**M1**
	internal energy increases (so temperature increases)	**A1**

Question	Answer	Marks
2(b)(iii)	$pV = NkT$ e.g. $N = \dfrac{1.10\times10^{5}\times540\times10^{-6}}{1.38\times10^{-23}\times300}$ $= 1.435 \times 10^{22}$ $\Delta E_k = (3/2)\ k\Delta TN$	C1
	$= (3/2) \times 1.38 \times 10^{23} \times (742 - 27) \times \dfrac{1.10\times10^{5}\times540\times10^{-6}}{1.38\times10^{-23}\times300}$	C1
	$= 212$ J	A1
2(c)	$E = mc\Delta\theta$ **and** $E = mL$	C1
	$\Delta\theta = (27 + 196)$ or 223	C1
	$E = 0.0240 \times 1.04 \times (27 + 196) + 0.0240 \times 199$ $= 10.3$ kJ	A1

Question	Answer	Marks
3(a)	P: total energy Q: potential energy R: kinetic energy	B2
3(b)	$E = ½m\omega^2 x_0^2$ **or** $E = ½mv_0^2$ **and** $v_0 = \omega x_0$	C1
	$6.4 \times 10^{-3} = \frac{1}{2} \times 0.130 \times \omega^2 \times 0.015^2$ ($\omega^2 = 438$) ($\omega = 20.9$)	C1
	$T = 2\pi / \omega$	C1
	$= 2\pi / 20.9$ $= 0.30$ s	A1
3(c)(i)	resistive forces	B1
3(c)(ii)	0.92^6	C1
	decrease in energy $= 6.4 – (6.4 \times 0.92^6)$ $= 2.5$ mJ	A1
3(c)(iii)	light damping because the amplitude of oscillations gradually reduces **or** light damping because the system still oscillates	B1

Question	Answer	Marks
4(a)	(electric) force is (directly) proportional to product of charges	**B1**
	force (between point charges) is inversely proportional to the square of their separation	**B1**
4(b)(i)	arrows showing tension upwards in direction of string, electric force horizontally to the right and weight vertically downwards and all three labelled	**B1**
4(b)(ii)	$F_E = \dfrac{96 \times 10^{-9} \times 64 \times 10^{-9}}{4 \times \pi \times 8.85 \times 10^{-12} \times 0.080^2}$ $(= 8.63 \times 10^{-3}\ \text{N})$	**C1**
	either angle to vertical $= \sin^{-1} 0.080 / 1.2$ $(= 3.82°)$	**C1**
	weight $= F_E / \tan 3.82 = 8.63 \times 10^{-3} / \tan 3.82$ $(= 0.129\ \text{N})$	**C1**
	mass = 0.129 / 9.81 = 0.013 kg	**A1**
	or $T \sin \theta = mg$ **and** $T \cos \theta = F_E$ **or** $\tan \theta = mg / F_E$	**(C1)**
	$\tan \theta = 1.2 / 0.080$	**(C1)**
	$m = (1.2 \times 8.63 \times 10^{-3}) / (0.080 \times 9.81)$ $= 0.013\ \text{kg}$	**(A1)**

Question	Answer	Marks
4(b)(iii)	$E_p = \dfrac{Q_1Q_2}{4\pi\varepsilon_o r} = \dfrac{96\times10^{-9}\times64\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.080}$ $= 6.9 \times 10^{-4}$ J	A1
4(c)(i)	towards the top of the page / towards plate P	B1
4(c)(ii)	$F = QE$ **and** $E = V / d$	C1
	$F = 1.6 \times 10^{-19} \times 250 / 0.018$ $= 2.2 \times 10^{-15}$ N	A1
4(c)(iii)	**either** the force is not (always) perpendicular to the velocity **or** the force is always in the same direction	B1

Question	Answer	Marks
5(a)	from graph ln Q = 2.9 (so Q = 18.2 μC)	**B1**
	$C = Q / V$	**C1**
	$= 18.2 / 12 = 1.5\ \mu F$	**A1**
5(b)	gradient = –0.25	**C1**
	gradient = $-1 / RC$	**C1**
	$R = 1 / (0.25 \times 1.5 \times 10^{-6})$ $= 2.7 \times 10^{6}\ \Omega$	**A1**
	or $\dfrac{Q}{Q_0} = e^{-t/CR}$ **or** $\ln Q - \ln Q_0 = \dfrac{-t}{CR}$	**(C1)**
	e.g. $\dfrac{4.95}{18.2} = e^{-5.2/(1.5 \times 10^{-6} R)}$ **or** $1.6 - 2.9 = 5.2 / (1.5 \times 10^{-6} R)$	**(C1)**
	$R = 2.7 \times 10^{6}\ \Omega$	**(A1)**

Question	Answer	Marks
5(c)	$W = ½\,QV$	**C1**
	$= ½ \times 18.2 \times 10^{-6} \times 12$ $= 1.1 \times 10^{-4}$ J	**A1**
	or $W = ½\,CV^2$	**(C1)**
	$= ½ \times 1.5 \times 10^{-6} \times 12^2$ $= 1.1 \times 10^{-4}$ J	**(A1)**
	or $W = ½\,Q^2 / C$	**(C1)**
	$= ½ \times (18.2 \times 10^{-6})^2 / 1.5 \times 10^{-6}$ $= 1.1 \times 10^{-4}$ J	**(A1)**
5(d)	straight line with different negative gradient starting from (0, 2.9)	**M1**
	straight line between $t = 0$ and at least $t = 5.0$ s with twice the gradient of the original line	**A1**

Question	Answer	Marks
6(a)	it is zero when (plane of) probe is parallel to the (magnetic) field (lines)	**B1**
	it is maximum when (plane of) probe is perpendicular to (magnetic) field (lines)	**B1**
6(b)(i)	number density of charge carriers	**B1**
6(b)(ii)	smaller value of n so greater Hall voltage / V_H	**B1**
6(c)	(36 mV corresponds to) 48 mT	**C1**
	use of 1.4 s or (8.6 – 7.2) s	**C1**
	$E = \Delta BAN / \Delta t$	**C1**
	$= \dfrac{48 \times 10^{-3} \times 0.018^2 \times \pi \times 780}{1.4}$ $= 0.027\,\text{V}$	**A1**

Question	Answer	Marks
7(a)	photon absorbed (by electron) and electron excited	B1
	photon energy equal to difference in (energy of two) energy levels	B1
	photon energy relates to a single wavelength / single frequency	B1
	electron de-excites and emits photon in any direction	B1
7(b)	$\frac{hc}{\lambda} = \Delta E$	C1
	uses 658 nm	C1
	$\frac{6.63\times10^{-34}\times3.00\times10^{8}}{658\times10^{-9}} = -E_1 - (-3.40 \times 1.60 \times 10^{-19})$ $E_1 = -2.42 \times 10^{-19}$ J	A1

Question	Answer	Marks
8(a)	234, 92 for the uranium nucleus	**B1**
	4, 2 for the alpha particle	**B1**
8(b)(i)	$N_0 = 0.874 / (238 \times 1.66 \times 10^{-27})$ $= 2.21 \times 10^{24}$	**A1**
8(b)(ii)	$A = \lambda N$	**C1**
	$= \dfrac{\ln 2}{87.7 \times 365 \times 24 \times 3600} \times 2.21 \times 10^{24}$ $= 5.54 \times 10^{14}$ Bq	**A1**
8(b)(iii)	power $= 5.54 \times 10^{14} \times 5.59 \times 10^{6} \times 1.60 \times 10^{-19}$	**C1**
	$= 496$ W	**A1**
8(b)(iv)	$65.3 = 100e^{-\frac{\ln 2}{87.7}t}$	**C1**
	$\ln 0.653 = -(\ln 2 / 87.7)\, t$ $t = 53.9$ years	**A1**
8(c)	advantage: less mass so less energy needed to launch probe	**B1**
	disadvantage: half-life shorter so will not provide power for as long	**B1**

Question	Answer	Marks
9(a)	piezo-electric crystal	**B1**
	(ultrasound) wave causes shape change / vibrations (of crystal)	**B1**
	shape change / vibrations causes e.m.f. (which is detected)	**B1**
9(b)(i)	93 V	**A1**
9(b)(ii)	2.7×10^{7} rad s^{-1}	**A1**
9(c)(i)	kg m^{-2} s^{-1}	**B1**
9(c)(ii)	$\rho = Z / c = 1.7 \times 10^{6} / 1600$ = 1100 kg m^{-3}	**A1**
9(c)(iii)	intensity reflection coefficient ≈ 1 **or** Z_1 and Z_2 are very different	**B1**
	almost no / no ultrasound transmitted (into air filled cavity)	**B1**

Question	Answer	Marks
10(a)	brighter star could be closer (to Earth)	**B1**
	brighter star could have a greater luminosity (in the visible wavelengths)	**B1**
10(b)	object with known luminosity	**B1**
10(c)(i)	$\frac{660.9-656.3}{656.3} \approx \frac{v}{3.0 \times 10^8}$ leading to 2.1×10^6 m s^{-1}	**B1**
10(c)(ii)	$v = H_0 d$	**C1**
	$d = 2.1 \times 10^6 / 2.3 \times 10^{-18}$ $= 9.1 \times 1023$ m	**A1**
10(c)(iii)	wavelength has increased / light is redshifted	**B1**
	star within galaxy is moving away / receding (from Earth)	**B1**
	Universe is expanding	**B1**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **February/March 2022**

MARK SCHEME

Maximum Mark: 100

Published

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Examples of how to apply the list rule
State **three** reasons…. [3]

A

1. Correct	✓	**2**
2. Correct	✓	
3. Wrong	×	

B
(4 responses)

1. Correct, Correct	✓, ✓	**3**
2. Correct	✓	
3. Wrong	ignore	

C
(4 responses)

1. Correct	✓	**2**
2. Correct, Wrong	✓, ×	
3. Correct	ignore	

D
(4 responses)

1. Correct	✓	**2**
2. Correct, CON (of 2.)	×, (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.)	× (discount 3)	

G
(5 responses)

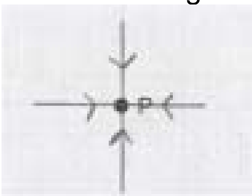
1. Correct	✓	**3**
2. Correct	✓	
3. Correct Correct CON (of 4.)	✓ ignore ignore	

H
(4 responses)

1. Correct	✓	**2**
2. Correct	×	
3. CON (of 2.) Correct	(discount 2) ✓	

I
(4 responses)

1. Correct	✓	**2**
2. Correct	×	
3. Correct CON (of 2.)	✓ (discount 2)	

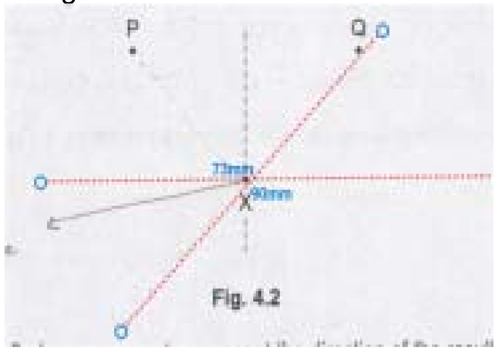
Question	Answer	Marks
1(a)	at least 4 straight radial lines to P 	**B1**
	all arrows pointing along the lines towards P	**B1**
1(b)	**Any 2 from:** gravitational force provides the centripetal force (centripetal or gravitational) force has constant magnitude (centripetal or gravitational) force is perpendicular to velocity (of moon) / direction of motion (of moon)	**B2**
1(c)(i)	$\frac{GMm}{r^2} = mr\omega^2$	**M1**
	$M = \frac{r^3\omega^2}{G}$ and gradient = $r^3\omega^2$ hence $M = \frac{\text{gradient}}{G}$ or $r^3 = GM \times 1/\omega^2$ so gradient = GM hence $M = \frac{\text{gradient}}{G}$	**A1**
1(c)(ii)	M = $4.1 \times 10^{23} / (6.0 \times 10^7 \times 6.67 \times 10^{-11})$ = $\mathbf{1.0 \times 10^{26}}$ kg	**B1**

Question	Answer	Marks
1(c)(iii)	$\dfrac{GMm}{r^2}=\dfrac{mv^2}{r}$ $\dfrac{GM}{r}=v^2$	C1
	$v^2=\dfrac{6.67\times10^{-11}\times1.0\times10^{26}}{1.2\times10^8}$ $v^2=5.6\times10^7\,\text{m s}^{-1}$	C1
	$v = 7500\,\text{m s}^{-1}$	A1

Question	Answer	Marks
2(a)	0	B1
2(b)	$pV = nRT$ (n =) $1.5\times10^5\times4.2\times10^{-3}/8.31\times540$	C1
	= **0.14** mol	A1
2(c)	missing pressure **1.5** ($\times10^5$)	B1
	both missing volumes **1.8** ($\times10^{-3}$)	B1
2(d)(i)	(ΔU:) increase in internal energy (of the system)	B1
	(q:) thermal energy supplied to the system	B1
	(W:) work done on system	B1

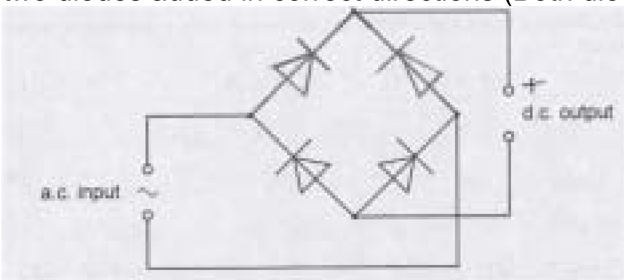
Question	Answer	Marks
2(d)(ii)	volume increases and work is done by the gas	**B1**
	temperature decreases and internal energy decreases	**B1**

Question	Answer	Marks
3(a)	upthrust, weight	**B1**
3(b)	upthrust greater than weight so (resultant force is) upwards	**B1**
3(c)(i)	A, g and ρ all constant so $F \propto x$	**B1**
	minus sign means F and x are in opposite directions	**B1**
3(c)(ii)	$\left(a = \frac{F}{m} \text{ so}\right)\ a = (-)\frac{Ag\rho x}{m}$	**M1**
	so $\omega^2 = \frac{Ag\rho}{m}$ hence $\omega = \sqrt{\frac{Ag\rho}{m}}$	**A1**
3(d)(i)	damping due to viscous forces	**B1**
3(d)(ii)	$(E =)\ \frac{1}{2} m\omega^2 x_0^{\,2}$	**C1**
	$\omega^2 = (-)$ gradient	**C1**
	$(E =)\ \frac{1}{2} m\omega^2 (x_1^{\,2} - x_2^{\,2})$ $= \frac{1}{2} \times 0.57 \times (2.3/0.020)(0.020^2 - 0.016^2)$ $= 4.7 \times 10^{-3}$ J	**A1**

Question	Answer	Marks
4(a)	direction of force	B1
	force on a positive charge	B1
4(b)(i)	$V = \dfrac{Q}{4\pi\varepsilon_o r}$ $\dfrac{4.0\times10^{-9}}{4\pi\varepsilon_o x} + \dfrac{-7.2\times10^{-9}}{4\pi\varepsilon_o(0.120 - x)} = 0$ $4(0.120 - x) = 7.2x$	C1
	$x = 0.043$ m	A1
4(b)(ii)	fields are in the same direction so no	B1
4(b)(iii)	straight arrow drawn leftwards from X in direction between extended line joining Q and X and the horizontal 	B1

Question	Answer	Marks
5(a)	(energy stored =) area under line or ½ QV = ½ × 8.0 × 1.2 × 10^{-4}	C1
	= **4.8** × **10^{-4}** J	A1
5(b)(i)	(τ=) RC	C1
	(τ=) 220 × 10^3 × (1.2 × 10^{-4}/8.0) = **3.3** s	A1
5(b)(ii)	$E \propto V^2$	C1
	(so time to) V_o / 3 $V = V_o e^{-t/RC}$	C1
	$\frac{V_o}{3} = V_o e^{-t/3.3}$ $\frac{1}{3} = e^{-t/3.3}$	C1
	t = 3.6 s	A1
5(c)	(total) capacitance is doubled	M1
	time constant is doubled	A1

Question	Answer	Marks
6(a)	less in smaller solenoid	**B1**
6(b)	greater in smaller solenoid	**B1**
6(c)(i)	<u>direction</u> of (induced) e.m.f.	**M1**
	such as to (produce effects that) oppose the <u>change</u> that caused it	**A1**
6(c)(ii)	change of flux (linkage) in smaller solenoid induces e.m.f. in smaller solenoid	**B1**
	(induced) current in smaller solenoid causes field around it	**B1**
	the two fields (interact to) create an attractive force	**B1**

Question	Answer	Marks
7(a)(i)	two diodes added in correct directions (Both diodes pointing inwards and upwards), correct symbols only 	**B1**
7(a)(ii)	'+' anywhere on upper output wire	**B1**
7(b)(i)	$\omega = 2\pi / T$ $= 2\pi / 2.5$ $= 0.80\ \pi$ or $4\pi / 5$ or 2.5	**C1**
	(V =) **3.5 sin (0.8π *t*)** or 3.5 sin (4π t / 5) or 3.5 sin (2.5 t)	**A1**

Question	Answer	Marks
7(b)(ii)	$(P=)\dfrac{V^2}{2R}$ or $(P=)\dfrac{V_{r.m.s.}{}^2}{R}$ $=\dfrac{3.5^2}{2\times 12}$ or $\dfrac{2.47^2}{12}$	**C1**
	= 0.51 W	**A1**

Question	Answer	Marks
8(a)	$\lambda = \dfrac{h}{p}$ or $\lambda = \dfrac{h}{mv}$	**M1**
	where *h* is the Planck constant **and** *p* is the momentum (of particle) / *mv* is the momentum (of particle) / *m* is the mass (of particle) and *v* is the velocity (of particle)	**A1**
8(b)(i)	(electron) diffraction	**B1**
8(b)(ii)	moving electrons behave like waves	**B1**
8(b)(iii)	spacing between atoms ≈ wavelength of electron *or* diameter of atom ≈ wavelength of electron	**B1**
8(b)(iv)	Any one of: • wavelength has decreased • electron had greater momentum	**M1**
	so (accelerating) p.d. was increased	**A1**

Question	Answer	Marks
9(a)	207, 82 for lead	**B1**
	4, 2 for alpha	**B1**
9(b)(i)	(half-life found as) 0.52 s or correctly read points substituted into $N = N_0 e^{-\lambda t}$ $\lambda = \dfrac{0.693}{t_{1/2}}$ $\lambda = \dfrac{0.693}{0.52}$	**C1**
	λ = **1.3 s^{-1}**	**A1**
9(b)(ii)	$A = \lambda N$ $= 1.3 \times 24 \times 10^{12}$ $= 3.1 \times 10^{13}$ Bq	**A1**
9(b)(iii)	upwards curve of decreasing gradient starting from (0,0)	**B1**
	passes through (0.52, 12) and (1.2, 18.8)	**B1**
9(c)(i)	16×10^{12} and 7.2×10^{12}	**C1**
	$6900 \times 10^{3} \times 1.6 \times 10^{-19}$ $(16 \times 10^{12} - 7.2 \times 10^{12}) \times 6900 \times 10^{3} \times 1.6 \times 10^{-19}$	**C1**
	= **9.7 J**	**A1**

Question	Answer	Marks
9(c)(ii)	lead nuclei have kinetic energy *or* gamma <u>photons</u> are also emitted	B1

Question	Answer	Marks
10(a)	energy = $mc\Delta T$	C1
	energy = ItV $(\Delta T =) \dfrac{0.40 \times 0.020 \times 75\,000 \times 0.95}{0.015 \times 130}$	C1
	=290 K	A1
10(b)	$I = I_o e^{-\mu t}$ $0.20 = e^{-0.22t}$	C1
	t = 7.3 cm	A1

Question	Answer	Marks
10(c)	*either* (linear) attenuation coefficients / μ <u>very</u> different for bone and muscle	**M1**
	(very) different amounts (of X-rays) absorbed so good contrast or (very) different intensities transmitted so good contrast	**A1**
	or (linear) attenuation coefficients / μ similar for blood and muscle	**(M1)**
	similar amounts (of X-rays) absorbed so poor contrast or similar intensities transmitted so poor contrast	**(A1)**

Question	Answer	Marks
11(a)	substance containing radioactive nuclei that is introduced into the body *or* substance containing radioactive nuclei that is absorbed by the tissue being studied	**B1**
11(b)(i)	a particle interacting with its antiparticle so that mass is converted into energy	**B1**
11(b)(ii)	electron(s) and positron(s)	**B1**
11(c)(i)	$E = 2mc^2$ $= 2 \times 9.11 \times 10^{-31} \times 3.00 \times 10^{-82}$ $= 1.64 \times 10^{-13}$ J	**A1**

Question	Answer	Marks
11(c)(ii)	$\lambda = \dfrac{2hc}{E}$ $= \dfrac{2 \times 6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{1.64 \times 10^{-13}}$	C1
	$= 2.43 \times 10^{-12}$ m	A1
11(d)	Any 3 from: • the two gamma photons travel in opposite directions • gamma photons detected (outside body / by detectors) • gamma photons arrive (at detector) at different times • determine location of production (of gamma) • image of tracer concentration in tissue produced	B3

Question	Answer	Marks
12(a)	total power of radiation emitted (by the star)	B1
12(b)	$F = \dfrac{L}{4\pi d^2}$ $= \dfrac{3.83 \times 10^{26}}{4 \times \pi \times 1.51 \times 10^{112}}$	C1
	$= 1340$ W m^{-2}	A1

Question	Answer	Marks
12(c)	$m = \dfrac{E}{c^2}$ $= \dfrac{3.83 \times 10^{26}}{3.00 \times 10^{82}}$ $= 4.26 \times 10^{9}$ kg	**A1**
12(d)	$L = 4\pi\sigma r^2 T^4$ $3.83 \times 10^{26} = 4 \times \pi \times 5.67 \times 10^{-8} \times 6.96 \times 10^{82} \times T^4$ leading to $T = 5770$ K	**B1**
12(e)	$\lambda_{(max)} \propto \dfrac{1}{T}$ $\dfrac{5.00 \times 10^{-7}}{\lambda} = \dfrac{9940}{5770}$	**C1**
	$\lambda = 2.90 \times 10^{-7}$ m	**A1**

Cambridge International AS & A Level

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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. 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)	force per unit mass	**B1**
1(b)(i)	lines drawn are radial from the surface	**B1**
	arrows show pointing towards planet	**B1**
1(b)(ii)	field lines show force (on satellite) is towards centre of planet **or** velocity of satellite is perpendicular to field lines	**B1**
	(gravitational) force perpendicular to velocity causes centripetal <u>acceleration</u>	**B1**
1(c)(i)	T = 24 hours	**C1**
	$a = r\omega^2$ **and** $\omega = 2\pi / T$ **or** $a = v^2 / r$ **and** $v = 2\pi r / T$ **or** $a = 4\pi^2 r / T^2$	**C1**
	$a = (4\pi^2 \times 6.4 \times 10^6) / (24 \times 60 \times 60)^2$ $= 0.034\ \text{m s}^{-2}$	**A1**
1(c)(ii)	identification of the two forces acting on the object as gravitational force and (normal) contact force	**M1**
	gravitational force and normal contact force are in opposite directions, and their resultant causes the (centripetal) acceleration	**A1**

Question	Answer	Marks
2(a)	(thermal) energy per unit mass (to cause temperature change)	**B1**
	(thermal) energy per unit change in temperature	**B1**
2(b)(i)	work done correct (0)	**B1**
	increase in internal energy correct (+*E*)	**B1**
2(b)(ii)	work done correct (–*W*) **and** increase in internal energy same as **(b)(i)**	**B1**
	thermal energy correct so that it adds to work done to give increase in internal energy	**B1**
2(c)	more thermal energy needed so specific heat capacity is greater	**B1**

Question	Answer	Marks
3(a)	p = pressure (of gas), V = volume (of gas) **and** k = Boltzmann constant	B1
	N = number of molecules	B1
	T = thermodynamic temperature	B1
3(b)	($pV = NkT$ and $pV = \frac{1}{3}Nm\langle c^2\rangle$ leading to) $NkT = \frac{1}{3}Nm\langle c^2\rangle$	M1
	algebra leading to $(3/2)kT = \frac{1}{2}m\langle c^2\rangle$ **and** use of $\frac{1}{2}m\langle c^2\rangle = E_K$ leading to $(3/2)kT = E_K$	A1
3(c)(i)	T = 296 K	C1
	$\frac{1}{2}m\langle c^2\rangle = (3/2)kT$ $\frac{1}{2} \times 5.31 \times 10^{-26} \times u^2 = (3/2) \times 1.38 \times 10^{-23} \times 296$	C1
	u = 480 m s^{-1}	A1
3(c)(ii)	line passing through (P, u)	B1
	horizontal straight line	B1

Question	Answer	Marks
4(a)(i)	x_0 = 8.0 cm	**A1**
4(a)(ii)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / 4.0 = 1.6$ rad s^{-1}	**A1**
4(a)(iii)	$E = ½m\omega^2 x_0^2$	**C1**
	$= ½ \times 36 \times 1.6^2 \times 0.080^2$	**C1**
	= 0.29 J	**A1**
4(b)	dome-shaped curve, starting and ending at $E_K = 0$	**B1**
	maximum E_K shown as 0.29 J	**B1**
	position of peak shown at h = 10.0 cm	**B1**
	line intercepts h-axis at h = 2.0 cm and at h = 18.0 cm	**B1**

Question	Answer	Marks
5(a)	work done per unit charge	**B1**
	work done (on charge) in moving positive charge from infinity (to the point)	**B1**
5(b)(i)	radius = 0.060 m	**A1**
5(b)(ii)	$V = Q / 4\pi\varepsilon_0 x$ $Q = (–)\ 850 \times 4\pi \times 8.85 \times 10^{–12} \times 0.060$ **or** $Q = (–)\ 850 \times 0.060 / 8.99 \times 10^{9}$ (*any correct pair of V and x values from curve*)	**C1**
	$Q = –\ 5.7 \times 10^{–9}$ C	**A1**
5(c)(i)	$E_P = Q^2 / 4\pi\varepsilon_0 x$ $= (5.67 \times 10^{–9})^2 / (4\pi \times 8.85 \times 10^{–12} \times 0.46)$	**C1**
	$= 6.3 \times 10^{–7}$ J	**A1**
5(c)(ii)	• force is repulsive so spheres move apart • force in direction of motion so speed increases • potential energy converted to kinetic energy so speed increases • force decreases with distance so acceleration decreases • momentum is conserved (at zero) (and masses are equal) so velocities are always equal and opposite *Any three points, 1 mark each*	**B3**

Question	Answer	Marks
6(a)	• p.d. across resistor = p.d. across capacitor • current (in resistor) proportional to p.d. across it • current causes capacitor to lose charge • charge (on capacitor) proportional to p.d. so p.d. decreases *Any two points, 1 mark each*	**B2**
	rate of change of p.d. decreases as p.d. decreases	**B1**
6(b)	Q_0 = 0.90 mC **and** at t = one time constant, $Q = Q_0$ exp (–1)	**B1**
	at t = one time constant, Q = 0.90 exp (–1) = 0.33 mC	**M1**
	evidence of graph reading: when Q = 0.33 mC, t = 5.5 s	**A1**
	or	
	evidence of two correct sets of readings for Q and t from the graph	**(B1)**
	correct substitution of Q and t values into $Q_2 = Q_1 \exp [(t_1 - t_2) / \tau]$	**(M1)**
	calculation to give τ = 5.5 s	**(A1)**
	or	
	read-off of half-life as 3.75 s	**(B1)**
	use of $Q = Q_0 \exp (-t / \tau)$ to show that τ = half-life / ln 2	**(M1)**
	τ = 3.75 / ln 2 = 5.4 s	**(A1)**

Question	Answer	Marks
6(b)	**or**	
	tangent drawn on *Q*–*t* graph and value of *Q* at exact same time as tangent read from graph	**(M1)**
	gradient of tangent correctly calculated	**(A1)**
	$\tau = Q$ / gradient used to correctly calculate a value for τ as 5.5 s	**(A1)**
6(c)(i)	$C = Q / V$	**C1**
	$= [(0.90 \times 10^{-3}) / 7.5] = 1.2 \times 10^{-4}$ C $= 120\ \mu$F	**A1**
6(c)(ii)	$R = \tau / C$	**C1**
	$= 5.5 / (1.2 \times 10^{-4})$ (= 45 800 Ω) = 46 kΩ	**A1**

Question	Answer	Marks
7(a)	force per unit current	**M1**
	force per unit length	**M1**
	current / wire is perpendicular to (magnetic) field (lines)	**A1**
7(b)(i)	current (in coil) is perpendicular to magnetic field (so force on wire)	**B1**
	force (on wire) is perpendicular to current and field (so is vertical) **or** current and field are both horizontal (so force is vertical)	**B1**
7(b)(ii)	$NBIL = mg$	**C1**
	$B = (2.16 \times 10^{-3} \times 9.81) / (40 \times 3.94 \times 0.0300)$	**C1**
	$= 4.48 \times 10^{-3}$ T	**A1**
7(b)(iii)	(magnetic) forces (on balance and newton meter) are (equal and) opposite	**B1**
	reading $= 0.563 - (2.16 \times 10^{-3} \times 9.81)$ $= 0.542$ N	**A1**

Question	Answer	Marks
8(a)	direction of induced e.m.f.	**M1**
	such as to (produce effects that) oppose the change that caused it	**A1**
8(b)(i)	*X* = 0.85 A	**A1**
	Y = 2π / 0.040	**C1**
	= 160 rad s^{-1}	**A1**
8(b)(ii)	two cycles of a sinusoidal curve with a period of 0.040 s	**B1**
	correct phase (i.e. V_2 max / min at t = 0, 0.02, 0.04, 0.06 and 0.08 s, and V_2 zero at t = 0.01, 0.03, 0.05, 0.07 s)	**B1**
	maximum / minimum V_2 shown (consistently) at ± 6.5 V	**B1**
8(b)(iii)	(magnitude of) V_2 is proportional to rate of change of (magnetic) flux	**B1**
	• V_2 is proportional to <u>gradient</u> of I_1–t curve • V_2 has maximum magnitude when I_1–t curve is steepest • V_2 is zero when I_1–t curve is horizontal / a maximum or minimum • V_2 changes sign when sign of gradient of I_1–t curve changes *Any two points, 1 mark each*	**B2**

Question	Answer	Marks
9(a)(i)	• energy of photon has a corresponding frequency • change in electron energy level emits a single photon • photon energy = difference in energy levels • discrete frequencies must have come from discrete energy gaps • discrete energy changes imply discrete energy levels *Any three points, 1 mark each*	**B3**
9(a)(ii)	transition (to – 3.400 eV) from X corresponds to 658 nm line	**C1**
	$E_1 - E_2 = hc / \lambda$	**C1**
	$E_1 - (-3.400) = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (658 \times 10^{-9} \times 1.60 \times 10^{-19})$ and so $E_1 = -1.51$ eV (*full substitution and answer needed*)	**A1**
9(b)(i)	redshift	**B1**
9(b)(ii)	moving away (from observer)	**B1**
9(b)(iii)	$\Delta\lambda / \lambda = v / c$ e.g. for 658 nm line: $\Delta\lambda$ = 686 – 658 (= 28 nm) (*other lines may be used*)	**C1**
	$28 / 658 = v / (3.00 \times 10^{8})$ (*other lines may be used*)	**C1**
	$v = 1.3 \times 10^{7}$ m s^{-1}	**A1**
9(c)	$v = H_0 d$	**C1**
	$H_0 = (1.3 \times 10^{7}) / (5.7 \times 10^{24})$ $= 2.3 \times 10^{-18}$ s^{-1}	**A1**

Question	Answer	Marks
10(a)(i)	introduction of tracer (into the body)	**M1**
	containing a β^+ emitter	**A1**
10(a)(ii)	positron interacts with electron	**B1**
	(pair) annihilation occurs	**B1**
	mass of particles converted into gamma photons	**B1**
10(b)	(annihilation of electron and positron) produces two photons	**B1**
	$E = (\Delta)mc^2$	**B1**
	$E = hf$ **and** $f = c / \lambda$ **or** $E = hc / \lambda$	**B1**
	$\lambda = \{[2\times]\ 6.63 \times 10^{-34} \times 3.00 \times 10^{8}\} / \{[2\times]\ 9.11 \times 10^{-31} \times (3.00 \times 10^{8})^2\}$ $= 2.4(3) \times 10^{-12}$ m or 2.4(3) pm (*full substitution and answer with unit needed*)	**B1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **October/November 2017**

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.

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Cambridge Assessment International Education

Question	Answer	Marks
1(a)(i)	direction or rate of transfer of (thermal) energy **or** (if different,) not in thermal equilibrium/energy is transferred	**B1**
1(a)(ii)	uses a property (of a substance) that changes with temperature	**B1**
1(b)	• temperature scale assumes linear change of property with temperature • physical properties may not vary linearly with temperature • agrees only at fixed points *Any 2 points.*	**B2**
1(c)(i)	$Pt = mc(\Delta)\theta$	**C1**
	$95 \times 6 \times 60 = 0.670 \times 910 \times \Delta\theta$	**M1**
	$\Delta\theta = 56\,°C$ so final temperature = 56 + 24 = 80 °C	**A1**
	or	
	$95 \times 6 \times 60 = 0.67 \times 910 \times (\theta - 24)$	**(M1)**
	so final temperature or $\theta = 80\,°C$	**(A1)**

Question	Answer	Marks
1(c)(ii)	**1.** sketch: straight line from (0,24) to (6,80)	**B1**
	2. temperature drop due to energy loss = (80 – 64) = 16 °C	**C1**
	energy loss = 0.670 × 910 × (80 – 64) = 9800 J	**A1**
	or	
	energy to raise temperature to 64 °C = 0.670 × 910 × (64 – 24)	**(C1)**
	= 24400 J loss = (95 × 6 × 60) – 24400 = 9800 J	**(A1)**

Question	Answer	Marks
2(a)	(angular frequency =) 2π × frequency **or** 2π / period	**B1**
2(b)(i)	**1.** displacement = 2.0 cm	**A1**
	2. amplitude = 1.5 cm	**A1**
2(b)(ii)	reference to displacement of oscillations **or** displacement from equilibrium position **or** displacement from 2.0 cm	**B1**
	straight line indicates acceleration ∝ displacement	**B1**
	negative gradient shows acceleration and displacement are in opposite directions	**B1**

Question	Answer	Marks
2(b)(iii)	ω^2 = (–)1 / gradient **or** ω^2 = (–)$\Delta a / \Delta s$ **or** a = (–)$\omega^2 x$ <u>and</u> correct value of x	**C1**
	= e.g. (1.8 / 0.03) or (0.9 / 0.015) or (1.2 / 0.02) etc. **or** 0.9 = $\omega^2 \times$ 0.015 = 60	**C1**
	f = √60 / 2π = 1.2 Hz	**A1**

Question	Answer	Marks
3(a)	force per unit mass	**B1**
3(b)	changes in height <u>much</u> less than radius of Earth	**M1**
	so (radial) field lines are almost parallel **or** $g = GM / R^2 \approx GM / (R + h)^2$	**A1**

Question	Answer	Marks
3(c)	gravitational force provides/is centripetal force	**B1**
	$GMm/r^2 = mv^2/r$	**C1**
	$v = (2\pi \times 1.5 \times 10^{11})/(3600 \times 24 \times 365) = 2.99 \times 10^4$ (m s^{-1})	**C1**
	$6.67 \times 10^{-11}M = 1.5 \times 10^{11} \times (2.99 \times 10^4)^2$	**C1**
	$M = 2.0 \times 10^{30}$ kg	**A1**
	or	
	$GMm/r^2 = mr\omega^2$	**(C1)**
	$\omega = 2\pi/(3600 \times 24 \times 365) = 1.99 \times 10^{-7}$ (rad s^{-1})	**(C1)**
	$6.67 \times 10^{-11}M = (1.5 \times 10^{11})^3 \times (1.99 \times 10^{-7})^2$	**(C1)**
	$M = 2.0 \times 10^{30}$ kg	**(A1)**
	or	
	$T^2 = 4\pi^2r^3/GM$	**(C2)**
	$M = 4\pi^2 \times (1.5 \times 10^{11})^3 / (\{3600 \times 24 \times 365\}^2 \times 6.67 \times 10^{-11})$	**(C1)**
	$= 2.0 \times 10^{30}$ kg	**(A1)**

Question	Answer	Marks
4(a)	• acts as 'return' (conductor) for signal • shielding from noise/crosstalk/interference *Two sensible suggestions, 1 mark each.*	**B2**
4(b)	• small bandwidth • (there is) noise/interference/crosstalk • large attenuation/energy loss • reflections due to poor impedance matching *Two sensible suggestions, 1 mark each.*	**B2**
4(c)	attenuation = $190 \times 14 \times 10^{-3}$ (= 2.66 dB)	**C1**
	ratio / dB = (–)10 lg(P_2 / P_1)	**C1**
	2.66 = –10 lg (P_{OUT} / P_{IN}) P_{OUT} / P_{IN} = 0.54	**C1**
	fractional loss = 1 – (P_{OUT} / P_{IN}) = 1 – 0.54 = 0.46	**A1**
	or	
	2.66 = 10 lg (P_{IN} / P_{OUT}) P_{IN} / P_{OUT} = 1.85	**(C1)**
	fractional loss = (P_{IN} – P_{OUT}) / P_{IN} = (1.85 – 1) / 1.85 = 0.46	**(A1)**

Question	Answer	Marks
5(a)(i)	force proportional to <u>product</u> of charges and inversely proportional to <u>square</u> of separation	**A1**
5(a)(ii)	curve starting at (R, F_C)	**B1**
	passing through (2R, 0.25F_C)	**B1**
	passing through (4R, 0.06F_C)	**B1**
5(b)	graph: E = 0 when current constant (0 to t_1, t_2 to t_3, t_4 to t_5)	**B1**
	stepped from t_1 to t_2 and t_3 to t_4	**B1**
	(steps) in opposite directions	**B1**
	later one larger in magnitude	**B1**

Question	Answer	Marks
6(a)(i)	$1/T = 1/(2C) + 1/C$	**C1**
	$T = ⅔C$ **or** $0.67C$	**A1**
6(a)(ii)	same charge on Q as on combination	**B1**
	so p.d. is 6.0 V	**B1**
6(b)	P: p.d. will decrease (from 3.0 V)	**B1**
	to zero	**B1**
	Q: p.d. will increase (from 6.0 V)	**B1**
	to 9.0 V	**B1**

Question	Answer	Marks
7(a)(i)	gain of amplifier is very large	**B1**
	V^+ is at earth (potential)	**B1**
	for amplifier not to saturate	**M1**
	difference between V^- and V^+ must be very small **or** V^- must be equal to V^+	**A1**
	or	
	if $V^- \neq V^+$ then feedback voltage	**(M1)**
	acts to reduce gap until $V^- = V^+$ when stable	**(A1)**
7(a)(ii)	input impedance is infinite	**B1**
	(so) current in R_1 = current in R_2	**B1**
	$(V_{IN} - 0) / R_1 = (0 - V_{OUT}) / R_2$	**B1**
	(gain =) $V_{OUT} / V_{IN} = - R_2 / R_1$	**B1**
7(b)	graph: correct inverted shape (straight diagonal line from (0,0) to a negative potential, then a horizontal line, then a straight diagonal line back to the t-axis at the point where $V_{IN} = 0$)	**B1**
	horizontal line at correct potential of (–)9.0 V	**B1**
	both ends of horizontal line occur at correct times (coinciding with when $V_{IN} = 2.0$ V)	**B1**

Question	Answer	Marks
8(a)	DERQ and CFSP	**B1**
8(b)(i)	force (on charge) due to magnetic field = force due to electric field **or** $Bqv = Eq$ **or** $v = E/B$	**B1**
	$E = V_H/d$	**B1**
	$V_H = Bvd$	**B1**
8(b)(ii)	use of $I = nAqv$ **and** $A = dt$	**M1**
	algebra clear leading to $V_H = BI/ntq$	**A1**
8(c)	(in metal,) n is very large	**M1**
	(therefore) V_H is small	**A1**

Question	Answer	Marks
9(a)	image of one slice/section	**(B1)**
	images (of one slice) taken from different angles	**(M1)**
	to give 2D image (of one slice)	**(A1)**
	(repeated for) many slices	**(M1)**
	to build up 3D image (of whole body/structure)	**(A1)**
	Max. 4 marks total	**4**
9(b)	evidence of subtraction of background (–26)	**C1**
	evidence of division by three	**C1**
	<table><tr><td>7</td><td>11</td></tr><tr><td>6</td><td>2</td></tr></table>	**A1**

Question	Answer	Marks
10(a)	heating depends on current^2/I^2	**B1**
	and current^2/I^2 is always positive	**B1**
	or	
	a.c. changes direction (every half cycle)	**(B1)**
	but heating effect is independent of current direction	**(B1)**
	or	
	voltage and current are always in phase in a resistor	**(B1)**
	so $V \times I$ is always positive	**(B1)**
	or	
	sketch graph drawn showing power against time	**(B1)**
	comment that power is always positive	**(B1)**
10(b)(i)	for same power (transmission, higher voltage) $\rightarrow$ lower current	**B1**
	lower current $\rightarrow$ less power loss in (transmission) cables	**B1**
10(b)(ii)	• voltage can be (easily) stepped up/down • transformers only work with a.c. • generators produce a.c. • easier to rectify than invert *Two sensible suggestions, 1 mark each.*	**B2**

Question	Answer	Marks
11(a)	packet/quantum of energy of electromagnetic/EM radiation	**B1**
11(b)(i)	$E = hf$ $1.1 \times 10^{6} \times 1.60 \times 10^{-19} = 6.63 \times 10^{-34} \times f$	**C1**
	$f = 2.7 \times 10^{20}$ (2.65×10^{20}) Hz	**A1**
11(b)(ii)	$p = h/\lambda = hf/c$ $= (6.63 \times 10^{-34} \times 2.65 \times 10^{20})/(3.00 \times 10^{8})$ **or** $p = E/c$ $= (1.1 \times 1.60 \times 10^{-13})/(3.00 \times 10^{8})$	**C1**
	$p = 5.9 \times 10^{-22}$ (5.87×10^{-22}) N s	**A1**
11(c)	$123 \times 1.66 \times 10^{-27} \times v = 5.87 \times 10^{-22}$	**C1**
	$v = 2.9 \times 10^{3}$ m s^{-1}	**A1**

Question	Answer	Marks
12(a)	• emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • dead-time of counter • background radiation *Any two points.*	**B2**
12(b)(i)	curve is not smooth **or** curve fluctuates/curve is jagged	**B1**
12(b)(ii)	clear evidence of allowance for background	**B1**
	half-life determined at least twice	**B1**
	half-life = 1.5 hours (*1 mark if in range 1.7–2.0; 2 marks if in range 1.4–1.6*)	**A2**
12(c)	**1.** half-life: no change	**M1**
	because decay is spontaneous/independent of environment	**A1**
	2. count rate (likely to be or could be) different/is random/cannot be predicted	**B1**

Cambridge International AS & A Level

PHYSICS **9702/43**

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.

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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	<u>‘List rule’ guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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.

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** $\omega = 2\pi / T$ **or** $mv^2 / R = GMm / R^2$ **and** $v = 2\pi R / T$ **or** $4\pi^2 mR / T^2 = GMm / R^2$	**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 • volume of a gas at constant pressure • e.m.f. of a thermocouple *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) **or** 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 ω = angular frequency	**A1**
3(b)(i)	$x_0 = 0.12$ m	**A1**
3(b)(ii)	$v = \omega\sqrt{(x_0^2 - x^2)}$ 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 $\omega = 1.7$ rad s^{-1}	**A1**
3(b)(iii)	$E = ½M\omega^2 x_0^2$	**C1**
	$0.050 = ½ \times M \times 1.67^2 \times 0.12^2$ $M = 2.5$ kg	**A1**
	or	
	$(E_K)_{max} = ½Mv_0^2$	**(C1)**
	$0.050 = ½\, M \times 0.20^2$ $M = 2.5$ 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**
	$= 2400 / 0.046$ $= 5.2 \times 10^4\ \text{N C}^{-1}$	**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
	$Q_0 = 24 \times 470 \times 10^{-6}$ $= 0.011\,\text{C}$	A1
5(a)(ii)	$I_0 = 24 / 5600$ $= 4.3 \times 10^{-3}\,\text{A}$	A1
5(a)(iii)	$\tau = RC$	C1
	$= 5600 \times 470 \times 10^{-6}$ $= 2.6\,\text{s}$	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 = $4.2 \times \sqrt{2}$ (= 5.9 V)	**B1**
	power = V^2 / R = $5.9^2 / 760$ = 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 **or** energy to remove electron from surface **or** energy to remove electron with zero kinetic energy	**B1**
8(b)(i)	photon energy = hf	**C1**
	number per unit time = $8.36 \times 10^{-3} / (1.36 \times 10^{15} \times 6.63 \times 10^{-34})$ $= 9.27 \times 10^{15}\ \text{s}^{-1}$	**A1**
8(b)(ii)	$hf = \Phi + E_{MAX}$	**C1**
	$\Phi = (1.36 \times 10^{15} \times 6.63 \times 10^{-34}) - (3.09 \times 10^{-19})$ $= 5.93 \times 10^{-19}\ \text{J}$	**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
	$= 9.86 \times 10^{27} / [4\pi \times (8.14 \times 10^{16})^2]$ $= 1.18 \times 10^{-7}$ W m^{-2}	A1
9(b)(ii)	$L = 4\pi\sigma r^2 T^4$ $9.86 \times 10^{27} = 4 \times \pi \times 5.67 \times 10^{-8} \times r^2 \times 9830^4$	C1
	radius = 1.22×10^9 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 **or** wavelength of peak intensity inversely proportional to temperature	B1

Question	Answer	Marks
10(a)(i)	cannot predict when a (particular) nucleus will decay **or** cannot predict which nucleus will decay next	**B1**
10(a)(ii)	not affected by external / environmental factors	**B1**
10(b)(i)	line fluctuates **or** trend is a straight line	**B1**
10(b)(ii)	straight line of best fit drawn on Fig. 10.1	**B1**
10(b)(iii)	$M = M_0 \exp(-\lambda t)$ so $\ln M = \ln M_0 - \lambda t$ so gradient = $-\lambda$ (and magnitude of gradient = λ)	**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 / λ = 0.693 / 0.28 = 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**

Cambridge Assessment International Education

Cambridge International AS & A Level

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.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the October/November 2022 series for most Cambridge IGCSE™, Cambridge International A and AS Level components and some Cambridge O Level components.

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	<u>'List rule' guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

Abbreviations

/	Alternative and acceptable answers for the same marking point.
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___	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.
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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** $\omega = 2\pi / T$ **or** $mv^2 / R = GMm / R^2$ **and** $v = 2\pi R / T$ **or** $4\pi^2 mR / T^2 = GMm / R^2$	**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 • volume of a gas at constant pressure • e.m.f. of a thermocouple *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**
	$T = 37.2\,°\text{C}$	**A1**
2(b)(ii)	use a liquid with a lower (specific) heat capacity (than mercury) **or** 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 ω = angular frequency	**A1**
3(b)(i)	$x_0 = 0.12$ m	**A1**
3(b)(ii)	$v = \omega\sqrt{(x_0^2 - x^2)}$ 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 $\omega = 1.7$ rad s^{-1}	**A1**
3(b)(iii)	$E = ½M\omega^2 x_0^2$	**C1**
	$0.050 = ½ \times M \times 1.67^2 \times 0.12^2$ $M = 2.5$ kg	**A1**
	or	
	$(E_K)_{max} = ½Mv_0^2$	**(C1)**
	$0.050 = ½\ M \times 0.20^2$ $M = 2.5$ 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**
	$= 2400 / 0.046$ $= 5.2 \times 10^4$ 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**
	$Q_0 = 24 \times 470 \times 10^{-6}$ $= 0.011\,\text{C}$	**A1**
5(a)(ii)	$I_0 = 24 / 5600$ $= 4.3 \times 10^{-3}\,\text{A}$	**A1**
5(a)(iii)	$\tau = RC$	**C1**
	$= 5600 \times 470 \times 10^{-6}$ $= 2.6\,\text{s}$	**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 = $4.2 \times \sqrt{2}$ (= 5.9 V)	B1
	power = V^2 / R = $5.9^2 / 760$ = 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 **or** energy to remove electron from surface **or** energy to remove electron with zero kinetic energy	**B1**
8(b)(i)	photon energy = hf	**C1**
	number per unit time = $8.36 \times 10^{-3} / (1.36 \times 10^{15} \times 6.63 \times 10^{-34})$ $= 9.27 \times 10^{15}\ \text{s}^{-1}$	**A1**
8(b)(ii)	$hf = \Phi + E_{MAX}$	**C1**
	$\Phi = (1.36 \times 10^{15} \times 6.63 \times 10^{-34}) - (3.09 \times 10^{-19})$ $= 5.93 \times 10^{-19}$ 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
	$= 9.86 \times 10^{27} / [4\pi \times (8.14 \times 10^{16})^2]$ $= 1.18 \times 10^{-7}$ W m^{-2}	A1
9(b)(ii)	$L = 4\pi\sigma r^2 T^4$ $9.86 \times 10^{27} = 4 \times \pi \times 5.67 \times 10^{-8} \times r^2 \times 9830^4$	C1
	radius = 1.22×10^9 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 **or** wavelength of peak intensity inversely proportional to temperature	B1

Question	Answer	Marks
10(a)(i)	cannot predict when a (particular) nucleus will decay **or** cannot predict which nucleus will decay next	**B1**
10(a)(ii)	not affected by external / environmental factors	**B1**
10(b)(i)	line fluctuates **or** trend is a straight line	**B1**
10(b)(ii)	straight line of best fit drawn on Fig. 10.1	**B1**
10(b)(iii)	$M = M_0 \exp(-\lambda t)$ so $\ln M = \ln M_0 - \lambda t$ so gradient = $-\lambda$ (and magnitude of gradient = λ)	**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 / λ = 0.693 / 0.28 = 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**

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **October/November 2017**

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.

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Question	Answer	Marks
1(a)(i)	direction or rate of transfer of (thermal) energy **or** (if different,) not in thermal equilibrium/energy is transferred	**B1**
1(a)(ii)	uses a property (of a substance) that changes with temperature	**B1**
1(b)	• temperature scale assumes linear change of property with temperature • physical properties may not vary linearly with temperature • agrees only at fixed points *Any 2 points.*	**B2**
1(c)(i)	$Pt = mc(\Delta)\theta$	**C1**
	$95 \times 6 \times 60 = 0.670 \times 910 \times \Delta\theta$	**M1**
	$\Delta\theta = 56\,°C$ so final temperature = 56 + 24 = 80 °C	**A1**
	or	
	$95 \times 6 \times 60 = 0.67 \times 910 \times (\theta - 24)$	**(M1)**
	so final temperature or $\theta = 80\,°C$	**(A1)**

Question	Answer	Marks
1(c)(ii)	**1.** sketch: straight line from (0,24) to (6,80)	**B1**
	2. temperature drop due to energy loss = (80 – 64) = 16 °C	**C1**
	energy loss = 0.670 × 910 × (80 – 64) = 9800 J	**A1**
	or	
	energy to raise temperature to 64 °C = 0.670 × 910 × (64 – 24)	**(C1)**
	= 24400 J loss = (95 × 6 × 60) – 24400 = 9800 J	**(A1)**

Question	Answer	Marks
2(a)	(angular frequency =) 2π × frequency **or** 2π / period	**B1**
2(b)(i)	**1.** displacement = 2.0 cm	**A1**
	2. amplitude = 1.5 cm	**A1**
2(b)(ii)	reference to displacement of oscillations **or** displacement from equilibrium position **or** displacement from 2.0 cm	**B1**
	straight line indicates acceleration ∝ displacement	**B1**
	negative gradient shows acceleration and displacement are in opposite directions	**B1**

Question	Answer	Marks
2(b)(iii)	ω^2 = (–)1 / gradient **or** ω^2 = (–)$\Delta a / \Delta s$ **or** a = (–)$\omega^2 x$ <u>and</u> correct value of x	**C1**
	= e.g. (1.8 / 0.03) or (0.9 / 0.015) or (1.2 / 0.02) etc. **or** 0.9 = $\omega^2 \times 0.015$ = 60	**C1**
	f = $\sqrt{60} / 2\pi$ = 1.2 Hz	**A1**

Question	Answer	Marks
3(a)	force per unit mass	**B1**
3(b)	changes in height <u>much</u> less than radius of Earth	**M1**
	so (radial) field lines are almost parallel **or** $g = GM / R^2 \approx GM / (R + h)^2$	**A1**

Question	Answer	Marks
3(c)	gravitational force provides/is centripetal force	**B1**
	$GMm/r^2 = mv^2/r$	**C1**
	$v = (2\pi \times 1.5 \times 10^{11})/(3600 \times 24 \times 365) = 2.99 \times 10^4$ (m s^{-1})	**C1**
	$6.67 \times 10^{-11} M = 1.5 \times 10^{11} \times (2.99 \times 10^4)^2$	**C1**
	$M = 2.0 \times 10^{30}$ kg	**A1**
	or	
	$GMm/r^2 = mr\omega^2$	**(C1)**
	$\omega = 2\pi/(3600 \times 24 \times 365) = 1.99 \times 10^{-7}$ (rad s^{-1})	**(C1)**
	$6.67 \times 10^{-11} M = (1.5 \times 10^{11})^3 \times (1.99 \times 10^{-7})^2$	**(C1)**
	$M = 2.0 \times 10^{30}$ kg	**(A1)**
	or	
	$T^2 = 4\pi^2 r^3/GM$	**(C2)**
	$M = 4\pi^2 \times (1.5 \times 10^{11})^3 / (\{3600 \times 24 \times 365\}^2 \times 6.67 \times 10^{-11})$	**(C1)**
	$= 2.0 \times 10^{30}$ kg	**(A1)**

Question	Answer	Marks
4(a)	• acts as 'return' (conductor) for signal • shielding from noise/crosstalk/interference *Two sensible suggestions, 1 mark each.*	**B2**
4(b)	• small bandwidth • (there is) noise/interference/crosstalk • large attenuation/energy loss • reflections due to poor impedance matching *Two sensible suggestions, 1 mark each.*	**B2**
4(c)	attenuation = $190 \times 14 \times 10^{-3}$ (= 2.66 dB)	**C1**
	ratio / dB = (–)10 $\lg(P_2 / P_1)$	**C1**
	$2.66 = -10 \lg(P_{OUT} / P_{IN})$ $P_{OUT} / P_{IN} = 0.54$	**C1**
	fractional loss $= 1 - (P_{OUT} / P_{IN}) = 1 - 0.54$ $= 0.46$	**A1**
	or	
	$2.66 = 10 \lg(P_{IN} / P_{OUT})$ $P_{IN} / P_{OUT} = 1.85$	**(C1)**
	fractional loss $= (P_{IN} - P_{OUT}) / P_{IN} = (1.85 - 1) / 1.85$ $= 0.46$	**(A1)**

Question	Answer	Marks
5(a)(i)	force proportional to <u>product</u> of charges and inversely proportional to <u>square</u> of separation	**A1**
5(a)(ii)	curve starting at (R, F_C)	**B1**
	passing through ($2R$, $0.25F_C$)	**B1**
	passing through ($4R$, $0.06F_C$)	**B1**
5(b)	graph: E = 0 when current constant (0 to t_1, t_2 to t_3, t_4 to t_5)	**B1**
	stepped from t_1 to t_2 and t_3 to t_4	**B1**
	(steps) in opposite directions	**B1**
	later one larger in magnitude	**B1**

Question	Answer	Marks
6(a)(i)	$1/T = 1/(2C) + 1/C$	**C1**
	$T = ⅔C$ **or** $0.67C$	**A1**
6(a)(ii)	same charge on Q as on combination	**B1**
	so p.d. is 6.0 V	**B1**
6(b)	P: p.d. will decrease (from 3.0 V)	**B1**
	to zero	**B1**
	Q: p.d. will increase (from 6.0 V)	**B1**
	to 9.0 V	**B1**

Question	Answer	Marks
7(a)(i)	gain of amplifier is very large	**B1**
	V^+ is at earth (potential)	**B1**
	for amplifier not to saturate	**M1**
	difference between V^- and V^+ must be very small **or** V^- must be equal to V^+	**A1**
	or	
	if $V^- \neq V^+$ then feedback voltage	**(M1)**
	acts to reduce gap until $V^- = V^+$ when stable	**(A1)**
7(a)(ii)	input impedance is infinite	**B1**
	(so) current in R_1 = current in R_2	**B1**
	$(V_{IN} - 0) / R_1 = (0 - V_{OUT}) / R_2$	**B1**
	(gain =) $V_{OUT} / V_{IN} = - R_2 / R_1$	**B1**
7(b)	graph: correct inverted shape (straight diagonal line from (0,0) to a negative potential, then a horizontal line, then a straight diagonal line back to the *t*-axis at the point where $V_{IN} = 0$)	**B1**
	horizontal line at correct potential of (–)9.0 V	**B1**
	both ends of horizontal line occur at correct times (coinciding with when V_{IN} = 2.0 V)	**B1**

Question	Answer	Marks
8(a)	DERQ and CFSP	**B1**
8(b)(i)	force (on charge) due to magnetic field = force due to electric field **or** $Bqv = Eq$ **or** $v = E/B$	**B1**
	$E = V_H/d$	**B1**
	$V_H = Bvd$	**B1**
8(b)(ii)	use of $I = nAqv$ **and** $A = dt$	**M1**
	algebra clear leading to $V_H = BI/ntq$	**A1**
8(c)	(in metal,) n is very large	**M1**
	(therefore) V_H is small	**A1**

Question	Answer	Marks
9(a)	image of one slice/section	**(B1)**
	images (of one slice) taken from different angles	**(M1)**
	to give 2D image (of one slice)	**(A1)**
	(repeated for) many slices	**(M1)**
	to build up 3D image (of whole body/structure)	**(A1)**
	Max. 4 marks total	**4**
9(b)	evidence of subtraction of background (–26)	**C1**
	evidence of division by three	**C1**
	<table><tr><td>7</td><td>11</td></tr><tr><td>6</td><td>2</td></tr></table>	**A1**

Question	Answer	Marks
10(a)	heating depends on current^2/I^2	**B1**
	and current^2/I^2 is always positive	**B1**
	or	
	a.c. changes direction (every half cycle)	**(B1)**
	but heating effect is independent of current direction	**(B1)**
	or	
	voltage and current are always in phase in a resistor	**(B1)**
	so $V \times I$ is always positive	**(B1)**
	or	
	sketch graph drawn showing power against time	**(B1)**
	comment that power is always positive	**(B1)**
10(b)(i)	for same power (transmission, higher voltage) $\rightarrow$ lower current	**B1**
	lower current $\rightarrow$ less power loss in (transmission) cables	**B1**
10(b)(ii)	• voltage can be (easily) stepped up/down • transformers only work with a.c. • generators produce a.c. • easier to rectify than invert *Two sensible suggestions, 1 mark each.*	**B2**

Question	Answer	Marks
11(a)	packet/quantum of energy of electromagnetic/EM radiation	**B1**
11(b)(i)	$E = hf$ $1.1 \times 10^{6} \times 1.60 \times 10^{-19} = 6.63 \times 10^{-34} \times f$	**C1**
	$f = 2.7 \times 10^{20}\,(2.65 \times 10^{20})$ Hz	**A1**
11(b)(ii)	$p = h/\lambda = hf/c$ $= (6.63 \times 10^{-34} \times 2.65 \times 10^{20})/(3.00 \times 10^{8})$ **or** $p = E/c$ $= (1.1 \times 1.60 \times 10^{-13})/(3.00 \times 10^{8})$	**C1**
	$p = 5.9 \times 10^{-22}\ (5.87 \times 10^{-22})$ N s	**A1**
11(c)	$123 \times 1.66 \times 10^{-27} \times v = 5.87 \times 10^{-22}$	**C1**
	$v = 2.9 \times 10^{3}$ m s^{-1}	**A1**

Question	Answer	Marks
12(a)	• emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • dead-time of counter • background radiation *Any two points.*	**B2**
12(b)(i)	curve is not smooth **or** curve fluctuates/curve is jagged	**B1**
12(b)(ii)	clear evidence of allowance for background	**B1**
	half-life determined at least twice	**B1**
	half-life = 1.5 hours (*1 mark if in range 1.7–2.0; 2 marks if in range 1.4–1.6*)	**A2**
12(c)	**1.** half-life: no change	**M1**
	because decay is spontaneous/independent of environment	**A1**
	2. count rate (likely to be or could be) different/is random/cannot be predicted	**B1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **October/November 2017**

MARK SCHEME

Maximum Mark: 100

Published

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Question	Answer	Marks
1(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of force between point masses	B1
1(b)	mass of Jupiter (M) = $(4/3)\pi R^3\rho$	B1
	$\omega = 2\pi/T$ **or** $v = 2\pi nR/T$	B1
	$(m)\omega^2 x = GM(m)/x^2$ **or** $(m)v^2/x = GM(m)/x^2$	M1
	substitution and correct algebra leading to $\rho T^2 = 3\pi n^3/G$	A1
1(c)(i)	$n = (4.32 \times 10^5)/(7.15 \times 10^4)$ **or** $n = 6.04$	C1
	$\rho \times (42.5 \times 3600)^2 = (3\pi \times 6.04^3)/(6.67 \times 10^{-11})$	C1
	$\rho = 1.33 \times 10^3\,\mathrm{kg\,m^{-3}}$	A1
1(c)(ii)	Jupiter likely to be a gas/liquid (at high pressure) [allow other sensible suggestions]	B1

Question	Answer	Marks
2(a)	(thermal) energy <u>per</u> (unit) mass (to cause change of state)	**B1**
	(energy required to cause/released in) change of state at constant temperature	**B1**
2(b)(i)	**1.** (work done on/against) the <u>atmosphere</u>	**B1**
	2. <u>water</u> as it turns from liquid to vapour	**M1**
	as potential energy of <u>molecules</u> increases	**A1**
	or	
	<u>surroundings</u> as its temperature rises	**(M1)**
	as energy is lost/transferred to surroundings	**(A1)**
2(b)(ii)	$VI - h = M / t \times L$ (where h = power loss) **or** $L = (VIt - Q) / M$ (where Q = energy loss)	**C1**
	$(14.2 \times 6.4) - (11.5 \times 5.2) = (9.1 - 5.0) \times L / 300$ **or** $L = [(14.2 \times 6.4) - (11.5 \times 5.2)] \times 300 / (9.1 - 5.0)$	**C1**
	$L = 2300\,\mathrm{J\,g^{-1}}$	**A1**

Question	Answer	Marks
3(a)(i)	angle (subtended) where arc (length) is equal to radius	**M1**
	(angle subtended) at the centre of a circle	**A1**
3(a)(ii)	angular frequency = $2\pi \times$ frequency **or** 2π / period	**B1**
3(b)(i)	c / ML^3 is a constant so acceleration is proportional to displacement	**B1**
	minus sign shows that acceleration and displacement are in opposite directions	**B1**
3(b)(ii)	$c / ML^3 = (2\pi f)^2$	**C1**
	$c = 4\pi^2 \times 3.2^2 \times 0.24 \times 0.65^3$	**C1**
	$= 27\ \text{kg m}^3\,\text{s}^{-2}$	**A1**

Question	Answer	Marks
4(a)	quartz/piezo-electric **and** crystal/transducer	**B1**
	p.d. across crystal causes it to distort	**B1**
	applying alternating p.d. causes oscillations/vibrations	**B1**
	when applied frequency is natural frequency, crystal resonates	**B1**
	natural frequency of crystal is in ultrasound range	**B1**
4(b)	small(er) structures can be resolved/observed/identified	**B1**

Question	Answer	Marks
5(a)	(0.2 ms) | 8.0 (mV) | 1000	**B1**
	(0.8 ms) | 5.8 (mV) | 0101	**B1**
5(b)	series of steps	**B1**
	all (step) changes are at 0.2 ms intervals	**B1**
	steps with correct levels at correct times (*1 mark if five levels correct; 2 marks if all levels correct*)	**B2**
5(c)	smaller step heights (possible)	**B1**
	smaller changes (in input signal) can be seen/reproduced/represented **or** (allows) more accurate <u>reproduction</u> (of the input signal)	**B1**

level	0	8	10	15	5	8
time / ms	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2

Question	Answer	Marks
6(a)	electric field lines are radial/normal to surface (of sphere)	**B1**
	electric field lines <u>appear</u> to originate from centre (of sphere)	**B1**
6(b)(i)	tangent drawn at x = 6.0 cm and gradient calculation attempted	**C1**
	$E = 9.0 \times 10^4\,\mathrm{N\,C^{-1}}$ (*1 mark if in range ±1.2; 2 marks if in range ±0.6*)	**A2**
	or	
	correct pair of values of V and x read from curved part of graph and substituted into $V = q/4\pi\varepsilon_0 x$	**(C1)**
	to give $q = 3.6 \times 10^{-8}\,\mathrm{C}$	**(C1)**
	(then $E = q/4\pi\varepsilon_0 x^2$ and x = 6 cm gives) $E = 9.0 \times 10^4\,\mathrm{N\,C^{-1}}$	**(A1)**
	or	
	($E = q/4\pi\varepsilon_0 x^2$ and $V = q/4\pi\varepsilon_0 x$ and so) $E = V/x$	**(C1)**
	giving $E = 5.4 \times 10^3/0.060$	**(C1)**
	$= 9.0 \times 10^4\,\mathrm{N\,C^{-1}}$	**(A1)**
6(b)(ii)	(R =) 2.5 cm	**B1**
	potential inside a conductor is constant **or** field strength inside a conductor zero (so gradient is zero)	**B1**

Question	Answer	Marks
7(a)(i)	(part of) the output is combined with the input	M1
	reference to potential/voltage/signal	A1
7(a)(ii)	• increased (operating) stability • increased bandwidth/range of frequencies over which gain is constant • less distortion (of output) *Any 2 points.*	B2
7(b)(i)	**1.** gain $= 3.6/(48 \times 10^{-3})$	C1
	$= 75$	A1
	2. gain $= 1 + R_F / R$ $75 = 1 + (92.5 \times 10^3)/R$	C1
	$R = 1300\,\Omega$	A1
7(b)(ii)	for 68 mV, gain $\times V_{IN} = 5.1$ (V) **or** output voltage would be greater than the supply voltage	M1
	amplifier would saturate (at 5.0 V) **or** output voltage = 5.0 (V)	A1

Question	Answer	Marks
8(a)(i)	DERQ and CFSP	**B1**
8(a)(ii)	charge carriers moving normal to (magnetic) field	**B1**
	charge carriers experience a force normal to I (and B)	**B1**
	charge build-up sets up electric field across the slice **or** build-up of charges results in a p.d. across the slice	**B1**
	charge stops building up/V_H becomes constant when $F_B = F_E$	**B1**
8(b)	V_H inversely proportional to n/number density of charge carriers	**B1**
	number density of charge carriers (n) lower in semiconductors so V_H larger for semiconductor slice	**B1**
	or	
	V_H proportional to v/drift velocity	**(B1)**
	(for same current) drift velocity (v) higher in semiconductors so V_H larger for semiconductor slice	**(B1)**

Question	Answer	Marks
9(a)	region (of space)	**B1**
	where an object/particle experiences a force	**B1**
9(b)	electric and magnetic fields normal to each other	**B1**
	velocity of particle normal to both fields	**B1**
	forces (on particle) due to fields are in opposite directions	**B1**
	forces are equal for particles with a particular speed/for a selected speed/for speed given by $v = E(q) / B(q)$	**B1**
9(c)(i)	path labelled Q shown undeviated	**B1**
9(c)(ii)	reasonable curve in field and no 'kink' on entering, labelled V	**B1**
	deviated 'upwards'	**B1**

Question	Answer	Marks
10(a)	λ_0 marked and graph line passing through $E_{MAX} = 0$ at $\lambda = \lambda_0$	**B1**
	graph line with λ always < λ_0	**B1**
	negative gradient with correct concave curvature	**B1**
10(b)	curve with negative gradient and correct concave curvature	**M1**
	not touching either axis	**A1**

Question	Answer	Marks
11(a)(i)	circles drawn only around the top left and bottom right diodes	**B1**
11(a)(ii)	B shown as (+)ve and A shown as (–)ve	**B1**
11(b)(i)	$V_{\text{r.m.s.}}$ (= 5.6 / √2) = 4.0 V	**A1**
11(b)(ii)	380 = 2π*f* **or** *f* = 60.5 Hz	**C1**
	number (= 2*f*) = 120	**A1**
11(c)(i)	peak values (all) unchanged	**B1**
	(all) minima shown at 4.0 V	**B1**
	three lines from near peak showing concave curves after leaving dotted line not 'kinked' and not cutting the peak reaching candidate's minimum at the point where the decay meets the next dotted line	**B1**
	three lines drawn along the dotted lines showing rise in voltage from minima back to peak values	**B1**
11(c)(ii)	mean p.d. is higher **or** r.m.s. p.d. is higher **or** capacitor supplies energy to resistor	**M1**
	so (mean) power increases	**A1**

Question	Answer	Marks
12(a)(i)	<u>nucleus</u> emits particles/EM radiation/ionising radiation	**B1**
	emission/release from unstable <u>nucleus</u> **or** emission from <u>nucleus</u> is random and/or spontaneous	**B1**
12(a)(ii)	probability of decay (of a nucleus) **or** fraction of (number of undecayed) nuclei that will decay	**M1**
	per unit time	**A1**
12(b)	energy is shared with another particle	**B1**
	mention of antineutrino	**B1**
12(c)(i)	number $= [(1.2 \times 10^{-9}) / 131] \times 6.02 \times 10^{23}$ **or** number $= (1.2 \times 10^{-3} \times 10^{-9}) / (131 \times 1.66 \times 10^{-27})$ $(= 5.51 \times 10^{12})$	**C1**
	$A = \lambda N$	**C1**
	$= [0.086 / (24 \times 3600)] \times 5.51 \times 10^{12}$ $= 5.5 \times 10^{6}$ Bq	**A1**
12(c)(ii)	$1 / 50 = \exp(-0.086t)$ **or** $1 / 50 = 0.5^{n}$	**C1**
	$t = 45$ days	**A1**

Cambridge International AS & A Level

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **May/June 2022**

MARK SCHEME

Maximum Mark: 100

Published

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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.

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. Within 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)(i)	(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(a)(ii)	$g = F / m$	**C1**
	$F = GMm / r^2$ and so $g = [GMm / r^2] / m = GM / r^2$	**A1**
1(b)(i)	$g = (6.67 \times 10^{-11} \times 7.35 \times 10^{22}) / (1.74 \times 10^6)^2 = 1.62\ \text{N kg}^{-1}$	**A1**
1(b)(ii)	fields (due to Earth and the Moon) have equal magnitudes	**B1**
	fields (due to Earth and the Moon) are in opposite directions	**B1**
1(b)(iii)	distance of X from Earth = $(3.84 \times 10^8 - x)$	**C1**
	$(G \times)\ 7.35 \times 10^{22} / x^2 = (G \times)\ 5.98 \times 10^{24} / (3.84 \times 10^8 - x)^2$	**C1**
	$x = 3.8 \times 10^7$ m	**A1**

Question	Answer	Marks
2(a)(i)	(vertically) downwards	**B1**
2(a)(ii)	magnetic force (on sphere) is perpendicular to its velocity	**B1**
	magnetic force perpendicular to velocity is the centripetal force **or** magnetic force perpendicular to velocity causes centripetal acceleration **or** acceleration perpendicular to velocity is centripetal (acceleration) **or** magnetic force does not change the speed of the sphere **or** magnetic force has constant magnitude	**B1**
2(b)	$mg = Eq$	**C1**
	$E = (1.6 \times 10^{-10} \times 9.81) / (0.27 \times 10^{-9})$ $= 5.8\ \text{N C}^{-1}$	**A1**
2(c)	centripetal force = magnetic force **or** $Bqv = mv^2 / r$	**B1**
	$B = mv / qr$	**C1**
	$= (1.6 \times 10^{-10} \times 0.78) / (0.27 \times 10^{-9} \times 3.4) = 0.14\ \text{T}$	**A1**

Question	Answer	Marks
3(a)(i)	a gas that obeys $pV \propto T$	**M1**
	where p = pressure, V = volume, T = thermodynamic temperature	**A1**
3(a)(ii)	T = (273 + 17) K	**C1**
	$n = pV / RT$ $= (1.2 \times 10^5 \times 0.24) / [8.31 \times (273 + 17)]$ = 12 mol	**A1**
3(b)(i)	work done $= p\Delta V$	**C1**
	$= 1.2 \times 10^5 \times (0.24 – 0.08)$ = 19200 J (= 19.2 kJ)	**A1**
3(b)(ii)	AB work done correct (19.2)	**A1**
	BC work done correct (0)	**A1**
	CA increase in internal energy correct (0) **and** CA thermal energy correct (31.6)	**A1**
	AB increase in internal energy calculated correctly from work done – 48.0	**A1**
	BC increase in internal energy correctly calculated so the final column adds up to zero **and** BC thermal energy same as increase in internal energy (Fully correct table: AB | 19.2 | –48.0 | –28.8 BC | 0 | 28.8 | 28.8 CA | –31.6 | 31.6 | 0)	**A1**

Question	Answer	Marks
4(a)	straight line through origin shows that *a* is proportional to *x*	B1
	negative gradient shows that *a* is in opposite direction to *x*	B1
4(b)(i)	$a_0 = \omega^2 x_0$ **or** $a = -\omega^2 x$ **or** $\omega^2 = -$ gradient	C1
	$\omega = \sqrt{(0.40 / 0.050)}$ $= 2.8\ \text{rad s}^{-1}$	A1
4(b)(ii)	$k = \omega^2 L$ $= 2.8^2 \times 1.24$	C1
	$= 9.7\ \text{m s}^{-2}$	A1
4(c)	(increasing *L* causes) ω to decrease **or** energy (= ½ $m\omega^2 x_0^2$) = ½ mkx_0^2 / L (and *L* increases)	M1
	so amplitude increases	A1

Question	Answer	Marks
5(a)(i)	conversion (from a.c.) to d.c.	**B1**
5(a)(ii)	full-wave (rectification)	**B1**
5(b)(i)	P labelled – **and** Q labelled +	**B1**
5(b)(ii)	V_{OUT} scale labelled 4 and 8 on the 2 cm tick marks	**B1**
	$T = 2\pi / \omega$ $= 2\pi / 25\pi$ $= 0.08$ s	**C1**
	t scale labelled 0.02, 0.04, 0.06, 0.08, 0.10, 0.12 on the 2 cm tick marks	**A1**
5(c)(i)	correct symbol used for capacitor and capacitor connected in parallel with the 1.2 kΩ resistor.	**B1**
5(c)(ii)	straight lines or curves, with negative decreasing gradients, drawn between adjacent peaks, from top of first peak to meet line going up to next peak	**B1**
	lines, from one peak to the line going up to the next peak, show a drop in p.d. of 1½ small squares	**B1**
5(c)(iii)	$V = 0.90 \times 6.0$ (= 5.4 V) **or** discharge time (for each cycle) = 0.034 s	**C1**
	$V = V_0 \exp(-t / RC)$ $5.4 = 6.0 \exp[-0.034 / (1.2 \times 10^3 \times C)]$	**C1**
	$C = 2.7 \times 10^{-4}$ F	**A1**

Question	Answer	Marks
6(a)	product of (magnetic) flux density and area	**M1**
	where area is perpendicular to the (magnetic) field	**A1**
6(b)(i)	$N\Phi = BAN$	**C1**
	$= 400 \times 10^{-3} \times 0.12^2 \times 8$	**C1**
	$= 0.046$ Wb	**A1**
6(b)(ii)	(line is a) straight line	**B1**
6(b)(iii)	(induced) e.m.f. = rate of change of flux linkage	**C1**
	e.m.f. $= N\Phi / t$ $= 0.046 / 0.60$ $= 0.077$ V	**A1**
6(c)	(induced e.m.f. causes) current flow (in the coil)	**B1**
	either	
	current (in magnetic field) causes forces to act on the coil	**B1**
	(opposite sides of) coil forced inwards	**B1**
	or	
	current causes dissipation of energy in the resistance of the coil	**(B1)**
	temperature of the coil rises	**(B1)**

Question	Answer	Marks
7(a)	quantum of energy	**M1**
	of electromagnetic radiation	**A1**
7(b)(i)	photoelectric effect	**B1**
7(b)(ii)	• there is a frequency below which no electrons are emitted **or** threshold frequency = 5.4×10^{14} Hz • work function of the metal = 3.6×10^{-19} J (or 2.2 eV) • E_{MAX} increases (linearly) with (increasing) frequency • gradient of the line is the Planck constant **or** gradient of the line is 6.7×10^{-34} J s *Any three bullet points, 1 mark each*	**B3**
7(c)(i)	different threshold frequency	**B1**
	(line has) same gradient but different intercept	**B1**
7(c)(ii)	photons have same energy	**B1**
	line unchanged	**B1**

Question	Answer	Marks
8(a)(i)	energy required to separate the nucleons (in the nucleus)	**M1**
	to infinity	**A1**
8(a)(ii)	curve starting close to the origin and forming a single peak	**B1**
	peak shown to left of centre, with steep line on LHS of peak and shallow line on RHS of peak	**B1**
8(b)(i)	fusion	**B1**
8(b)(ii)	both particles have low *A* values **or** both particles are at left-hand end of graph	**B1**
	He-3 has higher binding energy (per nucleon) than H-2	**B1**
8(c)	$\Delta m = [(2 \times 2.014102) - (3.016029 + 1.008665)]$ u (= 0.00351 u)	**C1**
	$E = \Delta mc^2$	**C1**
	$= 0.00351 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$ $(= 5.24 \times 10^{-13}$ J)	**C1**
	1.00 mol of deuterium forms 0.500 mol of helium-3	**C1**
	total energy $= 0.500 \times 6.02 \times 10^{23} \times 5.24 \times 10^{-13}$ $= 1.58 \times 10^{11}$ J	**A1**

Question	Answer	Marks
9(a)(i)	electrons are accelerated (by an applied p.d.)	**B1**
	electrons hit target	**B1**
	X-rays produced when electrons decelerate	**B1**
9(a)(ii)	images of the multiple sections are combined to create a 3-D image	**B1**
9(b)(i)	$I = I_0 \exp(-\mu x)$	**C1**
	$= I_0 \exp(-0.89 \times 5.6)$ $= 0.0068\ I_0$	**A1**
9(b)(ii)	$I = I_0 \exp(-2.4 \times 3.4) \times \exp(-0.89 \times 3.2)$	**C1**
	$= 1.7 \times 10^{-5}\ I_0$	**A1**
9(c)	comparison of intensities or values in **(b)** leading to conclusion consistent with these values	**B1**

Question	Answer	Marks
10(a)	wavelength of maximum intensity is inversely proportional to (thermodynamic) temperature	**B1**
10(b)(i)	λ_{MAX} = 0.50 μm for A **and** 0.65 μm for B	**C1**
	T = 5800 × (0.50 / 0.65) = 4500 K	**A1**
10(b)(ii)	(star B has) greater peak / average wavelength	**B1**
	(star B looks) redder	**B1**
10(c)(i)	apparent wavelength is greater **or** wavelength is greater than known value	**B1**
	(due to) movement of star away (from observer)	**B1**
10(c)(ii)	by examining the (lines in the) spectrum (of light from the star)	**B1**
	and comparing with known spectrum	**B1**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **May/June 2023**

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 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

This document consists of **16** 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.

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	<u>‘List rule’ guidance</u> 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.

Abbreviations

/	Alternative and acceptable answers for the same marking point.
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Mark categories

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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.

Question	Answer	Marks
1(a)(i)	force per unit mass	**B1**
1(a)(ii)	force per unit positive charge	**B1**
1(a)(iii)	similarity: • inversely proportional to distance (from point) • points of equal potential lie on concentric spheres • zero at infinite distance *Any point, 1 mark*	**B1**
	difference: • gravitational potential is (always) negative • electric potential can be positive or negative *Any point, 1 mark*	**B1**
1(b)(i)	$g = GM / r^2$	**M1**
	$E = Q / 4\pi\varepsilon_0 r^2$	**M1**
	algebra showing the elimination of r leading to $M / Q = (1 / 4\pi G\varepsilon_0)(g / E)$	**A1**
1(b)(ii)	$\alpha = 1 / (4\pi \times 6.67 \times 10^{-11} \times 8.85 \times 10^{-12}) = 1.35 \times 10^{20}$ (kg^2 C^{-2}) **or** $\alpha = (8.99 \times 10^{9}) / (6.67 \times 10^{-11}) = 1.35 \times 10^{20}$ (kg^2 C^{-2})	**A1**
1(c)(i)	$E = \alpha gQ / M$ $= (1.35 \times 10^{20} \times 9.81 \times 4.80 \times 10^{5}) / (5.98 \times 10^{24})$	**C1**
	$= 106$ N C^{-1} **or** 106 V m^{-1}	**A1**
1(c)(ii)	same (direction)	**B1**

Question	Answer	Marks
2(a)	horizontal force on sphere causes centripetal acceleration	**B1**
	weight of sphere is (now) equal to vertical component of tension **or** horizontal and vertical components (of force) (now) combine to give greater tension (in spring)	**B1**
	greater tension in spring so greater extension of spring	**B1**
2(b)(i)	$r = 10.8 \times \sin 27° = 4.9$ cm	**A1**
2(b)(ii)	$T \cos \theta = mg$ **or** $T \cos \theta = W$ **and** $W = mg$	**C1**
	$T \cos 27° = 0.29 \times 9.81$ leading to $T = 3.2$ N	**A1**
2(b)(iii)	$\Delta T = 3.2 - (0.29 \times 9.81)$	**C1**
	$k = \Delta T / \Delta x$ $= [3.2 - (0.29 \times 9.81)] / [10.8 - 8.5]$ $= 0.15$ N cm^{-1}	**A1**
2(c)(i)	centripetal acceleration $= (T \sin \theta) / m$ $= (3.2 \times \sin 27°) / 0.29$	**C1**
	$= 5.0$ m s^{-2}	**A1**

Question	Answer	Marks
2(c)(ii)	$a = r\omega^2$ **and** $\omega = 2\pi / T$ **or** $a = v^2 / r$ **and** $v = 2\pi r / T$	**C1**
	$T = 2\pi \times \sqrt{(0.049 / 5.0)}$ $= 0.62$ s	**A1**

Question	Answer	Marks
3(a)	no net thermal energy is transferred (between them)	**B1**
3(b)(i)	variation (of density with temperature) is linear **or** each temperature has a unique value of density	**B1**
3(b)(ii)	• variation (of density with temperature) is not linear • region where the density does not vary with temperature • different temperatures have the same density *Any two points, 1 mark each*	**B2**
3(c)(i)	boiling point = 80 °C	**A1**
3(c)(ii)	$Q = Pt$ **and** $t = 21$ s (thermal energy supplied = 810 × 21 = 17000 J)	**C1**
	$c = Q / m\Delta\theta$	**C1**
	thermal energy absorbed by beaker = 42 × 0.84 × (80 – 25) (= 1940 J)	**C1**
	s.h.c. of liquid = [(810 × 21) – (42 × 0.84 × (80 – 25))] / [120 × (80 – 25)] = 2.3 J g^{-1} K^{-1}	**A1**
3(d)	sketch: straight diagonal line from 25 °C to 100 °C **and** then horizontal at 100 °C	**B1**
	straight diagonal line starting at 25 °C with gradient approximately half that of the original line	**B1**

Question	Answer	Marks
4(a)	• particles are in (continuous) random motion • particles have negligible volume (compared with the gas) • negligible forces between particles (except during collisions) • (all) collisions (perfectly) elastic • time of collision negligible (in comparison with time between collisions) *Any two points, 1 mark each*	B2
4(b)(i)	(general starting equation) $pV = nRT$	C1
	$T = (2pV / nR)$ where R is the (molar) gas constant	A1
4(b)(ii)	sketch: straight vertical line XY from (V, 2p) to (V, p)	B1
	straight horizontal line YZ from (V, p) to (2V, p)	B1
	curve with gradient increasing from Z to X from (2V, p) to (V, 2p)	B1
4(b)(iii)	XY work done on gas correct (= 0)	B1
	ZX increase in internal energy correct (= 0)	B1
	YZ work done on gas correct (= $-pV$)	B1
	XY increase in internal energy such that the increase in internal energy column adds up to zero	B1
	all three thermal energies transferred such that $\Delta U = q + w$ in each row (completely correct answer: change | ΔU | Q | w X to Y | $-U$ | $-U$ | 0 Y to Z | [$+U$] | $U + pV$ | $-pV$ Z to X | 0 | $-W$ | [$+W$])	B1

Question	Answer	Marks
5(a)(i)	correct circuit symbol for a diode shown correctly connected in series with the wires leading into and out of the dotted box	**B1**
5(a)(ii)	smoothing / V_{OUT} is smoothed	**B1**
5(b)(i)	frequency = 1 / 0.04 = 25 Hz	**A1**
5(b)(ii)	$V = V_0 \exp(-t/RC)$ **and** $\tau = RC$ **or** $V = V_0 \exp(-t/\tau)$	**C1**
	$3.25 = 5.50 \exp(-0.020/\tau)$ leading to $\tau = 0.038$ s	**A1**
5(b)(iii)	$\tau = RC$	**C1**
	capacitance = 0.038 / 14000 $= 2.7 \times 10^{-6}$ F	**A1**
5(c)	V_{IN} has constant magnitude in both positive and negative directions	**B1**
	(so) V_{OUT} is (now) constant / V_{OUT} does not vary with time	**B1**

Question	Answer	Marks
6(a)	a region where a force acts on	**M1**
	a current-carrying conductor **or** a moving charge **or** a magnetic material / magnetic pole	**A1**
6(b)	concentric circles around the wire	**B1**
	spacing between circles increases with distance from wire	**B1**
	arrows showing direction of field is clockwise	**B1**
6(c)(i)	$F = BIL$	**C1**
	force per unit length $= BI$ $= 2.6 \times 10^{-3} \times 5.0$ $= 0.013\ \text{N m}^{-1}$	**A1**
6(c)(ii)	to the right	**B1**
6(c)(iii)	force (per unit length) has the same magnitude due to Newton's 3rd law	**B1**
	$0.013 = 1.5 \times 10^{-3} \times I$ current = 8.7 A	**A1**

Question	Answer	Marks
7(a)	wavelength associated with a moving particle	**B1**
7(b)(i)	(electron) diffraction	**B1**
7(b)(ii)	beam spreads out indicating diffraction **or** light and dark regions indicate an interference pattern	**B1**
	electron beam is behaving as a wave	**B1**
7(c)(i)	central blob and concentric rings	**B1**
	rings closer together (than previously)	**B1**
7(c)(ii)	(greater p.d. so) electrons to have greater momentum	**B1**
	greater momentum so decrease in (de Broglie) wavelength	**B1**
	lower (de Broglie) wavelength (for same grating spacing in crystal) causes: smaller diffraction angle **or** smaller angle of intensity maxima (for each order) **or** decrease in fringe spacing in diffraction pattern	**B1**

Question	Answer	Marks
8(a)(i)	specific acoustic impedance = 1200 × 1400 = 1.68×10^6 kg m^{-2} s^{-1}	**A1**
8(a)(ii)	density of air shown in table as 1.29	**A1**
	speed of sound in tissue shown in table as 1540	**A1**
8(b)(i)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ = $(1680000 - 440)^2 / (1680000 + 440)^2$	**C1**
	= 0.999	**A1**
8(b)(ii)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ = $(1680000 - 1680000)^2 / (1680000 + 1680000)^2$ = 0	**A1**
8(c)	without gel, (almost) all of the (incident) ultrasound is reflected (from skin)	**B1**
	with gel, (almost) all of the (incident) ultrasound is transmitted (into the body)	**B1**

Question	Answer	Marks
9(a)	time for activity (of sample) to halve	**B1**
9(b)	sketch: line with positive gradient starting at (0,0) and extending to t = 80 min	**B1**
	exponential curve, extending from t = 0 to t = 80 min, with gradient of steadily decreasing magnitude	**B1**
	line passing through (0,0), (20, $0.5N_0$) and (40, $0.75\ N_0$)	**B1**
9(c)(i)	every (undecayed) nucleus has the same probability of decay	**M1**
	fewer (undecayed) nuclei remaining (with time), so fewer will decay (in a given time interval)	**A1**
9(c)(ii)	• sample emits in all directions but detector only captures emissions in one direction • some emissions are absorbed before reaching detector • some emissions are scattered within the sample • simultaneous arrival of multiple particles only registers once • some particles may reach detector but not cause ionisation *Any two points, 1 mark each*	**B2**
	measured count rate is less than the activity	**B1**

Question	Answer	Marks
10(a)	speed is (directly) proportional to distance	**M1**
	speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer	**A1**
10(b)	$F = L / (4\pi d^2)$	**C1**
	$= (3.8 \times 10^{31}) / [4\pi \times (1.8 \times 10^{24})^2]$ $= 9.3 \times 10^{-19}\,\text{W m}^{-2}$	**A1**
10(c)(i)	galaxy is moving away (from the Earth)	**B1**
	wavelength (of light from the galaxy) increased by the Doppler effect / due to redshift	**B1**
10(c)(ii)	$\Delta\lambda / \lambda = v / c$ $v = [(492 - 486) \times 3.00 \times 10^8] / 486$ $(v = 3.7 \times 10^6\,\text{m s}^{-1})$	**C1**
	$H_0 = v / d$	**C1**
	$= (3.7 \times 10^6) / (1.8 \times 10^{24})$ $= 2.1 \times 10^{-18}\,\text{s}^{-1}$	**A1**

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **May/June 2017**

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.

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Cambridge is publishing the mark schemes for the May/June 2017 series for most Cambridge IGCSE®, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

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Question	Answer	Marks
1(a)	gravitational force (of attraction between satellite and planet)	**B1**
	provides / is centripetal force (on satellite about the planet)	**B1**
1(b)	$M = (4/3) \times \pi R^3 \rho$	**B1**
	$\omega = 2\pi / T$ **or** $v = 2\pi nR / T$	**B1**
	$GM / (nR)^2 = nR\omega^2$ **or** v^2 / nR	**M1**
	substitution clear to give $\rho = 3\pi n^3 / GT^2$	**A1**
1(c)	$n = (3.84 \times 10^5) / (6.38 \times 10^3) = 60.19$ or 60.2	**C1**
	$\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$	**C1**
	$\rho = 5.54 \times 10^3\ \text{kg m}^{-3}$	**A1**

Question	Answer	Marks
2(a)	e.g. period = 3 / 2.5	**C1**
	frequency = 0.83 Hz	**A1**
2(b)	light (damping)	**B1**
2(c)	at 2.7 s, A_0 = 1.5 (cm)	**B1**
	energy $= \frac{1}{2} m \times 4\pi^2 f^2 A_0^2$	**B1**
	$= \frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$ $= 5.51 \times 10^{-4}$ (J)	**C1**
	at 7.5 s, A_0 = 0.75 (cm)	**B1**
	energy $= \frac{1}{4} \times 5.51 \times 10^{-4}$ **or** energy $= \frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	**C1**
	energy $= 1.38 \times 10^{-4}$ (J) change $= (5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	**A1**

Question	Answer	Marks
3(a)(i)	signal consists of (a series of) 1s and 0s **or** offs and ons **or** highs and lows	**B1**
3(a)(ii)	component X: parallel-to-serial converter	**B1**
	component Y: DAC/digital-to-analogue converter	**B1**
3(a)(iii)	sample the (analogue) signal	**M1**
	at regular intervals and converts the analogue number to a digital number	**A1**
3(b)(i)	attenuation in fibre = 84 $\times$ 0.19 (= 16 dB)	**C1**
	ratio = 16 + 28 = 44 dB	**A1**
3(b)(ii)	ratio / dB = 10 lg (P_2 / P_1)	**C1**
	44 = 10 lg ({9.7 $\times$ 10^{-3}} / P) **or** –44 = 10 lg (P / {9.7 $\times$ 10^{-3}})	**C1**
	power = 3.9 $\times$ 10^{-7} W	**A1**

Question	Answer	Marks
4(a)	random/haphazard	B1
	constant velocity **or** speed in a straight line between collisions **or** distribution of speeds/different directions	B1
4(b)	(small) specks of light/bright specks/pollen grains/dust particles/smoke particles	M1
	moving haphazardly/randomly/jerky/in a zigzag fashion	A1
4(c)(i)	$pV = \frac{1}{3} Nm\langle c^2\rangle$ $1.05 \times 10^5 \times 0.0240 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	C1
	$\langle c^2\rangle = 1.89 \times 10^6$	C1
	or	
	$\frac{1}{2} m\langle c^2\rangle = (3/2)\, kT$ $0.5 \times (4.00 \times 10^{-3} / 6.02 \times 10^{23}) \times \langle c^2\rangle = 1.5 \times 1.38 \times 10^{-23} \times 300$	(C1)
	$\langle c^2\rangle = 1.87 \times 10^6$	(C1)
	or	
	$nRT = \frac{1}{3} Nm\langle c^2\rangle$ $1.00 \times 8.31 \times 300 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	(C1)
	$\langle c^2\rangle = 1.87 \times 10^6$	(C1)
	$c_{\text{r.m.s.}} = 1.37 \times 10^3\ \text{m s}^{-1}$	A1

Question	Answer	Marks
4(c)(ii)	$\langle c^2 \rangle \propto T$	**C1**
	$\langle c^2 \rangle$ at 177 °C = $1.89 \times 10^6 \times (450 / 300)$	**C1**
	$c_{\text{r.m.s.}}$ at 177 °C = $1.68 \times 10^3\ \text{m s}^{-1}$	**A1**

Question	Answer	Marks
5(a)	(loss in) kinetic energy of α-particle = $Qq / 4\pi\varepsilon_0 r$ **or** $7.7 \times 10^{-13} = Qq / 4\pi\varepsilon_0 r$	**C1**
	$7.7 \times 10^{-13} = 8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / r$	**M1**
	$r = 4.7 \times 10^{-14}$ m r is closest distance of approach so radius less than this	**A1**
5(b)	force = $Qq / 4\pi\varepsilon_0 r^2 = 4\text{u} \times a$	**C1**
	$8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / (4.7 \times 10^{-14})^2 = 4 \times 1.66 \times 10^{-27} \times a$	**C1**
	$a = 2.5 \times 10^{27}\ \text{m s}^{-2}$	**A1**
5(c)	so that single interactions between nucleus and α-particle can be studied **or** so that multiple deflections with nucleus do not occur	**B1**

Question	Answer	Marks
6(a)(i)	lamp needs ‘high’ power/‘large’ current/‘large’ voltage	**B1**
	op-amp can deliver only a small current/small voltage	**B1**
6(a)(ii)	correct symbol for relay coil connected between output and earth	**B1**
	switch between mains supply and lamp	**B1**
6(b)(i)	vary light intensity at which lamp is switched on/off	**B1**
6(b)(ii)	so that relay operates for only one current/voltage direction **or** so that relay/lamp operates for either dark or light conditions	**B1**
6(c)	when light level increases, LDR resistance decreases	**B1**
	(R_{LDR} low,) so $V^- > V^+$, so V_{OUT} negative/–5 V (must be consistent with B1 mark)	**M1**
	or	
	when light level decreases, LDR resistance increases	**(B1)**
	(R_{LDR} high,) so $V^- < V^+$, so V_{OUT} is positive/+5 V (must be consistent with B1 mark)	**(M1)**
	lamp comes on as light level decreases **or** lamp goes off as light level increases	**A1**

Question	Answer	Marks
7(a)	(magnetic) force (always) normal to velocity/direction of motion	**M1**
	(magnitude of magnetic) force constant **or** speed is constant/kinetic energy is constant	**M1**
	so provides the centripetal force	**A1**
7(b)	increase in KE = loss in PE **or** $\frac{1}{2} mv^2 = qV$	**M1**
	$p = mv$ with algebra leading to $p = \sqrt{(2mqV)}$	**A1**
7(c)	$Bqv = mv^2 / r$ $mv = Bqr$ **or** $p = Bqr$	**C1**
	$(2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2} = B \times 1.60 \times 10^{-19} \times 0.074$	**C1**
	$B = 5.0 \times 10^{-4}$ T	**A1**
7(d)	greater momentum	**M1**
	($p = Bqr$ and) so r increased	**A1**

Question	Answer	Marks
8	strong (uniform) magnetic field	**B1**
	* <u>nuclei</u> precess/rotate about field (direction)	
	radio frequency pulse/RF pulse (applied)	**B1**
	* RF or pulse is at Larmor frequency / frequency of precession	
	causes resonance / excitation (of nuclei)/nuclei to absorb energy	**B1**
	on relaxation/de-excitation, nuclei emit RF/pulse	**B1**
	* (emitted) RF/pulse detected and processed	
	non-uniform field (superposed on uniform field)	**B1**
	allows positions of (resonating) <u>nuclei</u> to be determined	**B1**
	* allows for position of detection to be changed/different slices to be studied	
	max. 2 of additional detail points marked *	**B2**

Question	Answer	Marks
9(a)(i)	core reduces loss of (magnetic) flux linkage/improves flux linkage	**B1**
9(a)(ii)	reduces (size of eddy) currents in core	**B1**
	(so that) heating of core is reduced	**B1**
9(b)	alternating voltage gives rise to changing magnetic flux in core	**M1**
	(changing) flux links the secondary coil	**A1**
	induced e.m.f. (in secondary) only when flux is changing/cut	**B1**

Question	Answer	Marks
10(a)(i)	penetration of beam	**M1**
	greater hardness means greater penetration/shorter wavelength/higher frequency/higher photon energy	**A1**
10(a)(ii)	greater accelerating potential difference **or** greater p.d. between anode and cathode	**B1**
10(b)	$I = I_0 \exp(-\mu x)$ ratio = (exp {–1.5 × 2.9}) / (exp {–4.0 × 0.95}) (= exp {–0.55})	**C1**
	= 0.58	**A1**

Question	Answer	Marks
11(a)	electrons (in gas atoms/molecules) interact with photons	**B1**
	photon energy causes electron to move to higher energy level/to be excited	**B1**
	photon energy = difference in energy of (electron) energy levels	**B1**
	when electrons de-excite, photons emitted in all directions (so dark line)	**B1**
11(b)(i)	photon energy $\propto 1/\lambda$	**C1**
	energy = 1.68 eV	**A1**
	or	
	$E = hc/\lambda$ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / (740 \times 10^{-9})$ $= 2.688 \times 10^{-19}$ J	**(C1)**
	energy = 1.68 eV	**(A1)**
11(b)(ii)	3.4 eV → 1.5 eV 3.4 eV → 0.85 eV 3.4 eV → 0.54 eV *all correct and none incorrect 2/2* *2 correct and 1 incorrect or only 2 correctly drawn 1/2*	**B2**

Question	Answer	Marks
12(a)	$x = 7$	**A1**
12(b)(i)	$E = mc^2$	**C1**
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $= 1.494 \times 10^{-10}$ J	**C1**
	division by 1.6×10^{-13} clear to give 934 MeV	**A1**
12(b)(ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ **or** $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	**C1**
	$= 0.21053$ u	**C1**
	energy $= 0.21053 \times 934$ $= 197$ MeV	**A1**
12(c)	kinetic energy of nuclei/particles/products/fragments	**B1**
	γ–ray photon energy	**B1**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 2023**

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.

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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	<u>'List rule' guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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.

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)	$GMm / R^2 = mR\omega^2$	**M1**
	$\omega = 2\pi / T$ <u>and</u> algebra leading to $4\pi^2 R^3 = GMT^2$	**A1**
	or	
	$GMm / R^2 = mv^2 / R$	**(M1)**
	$v = 2\pi R / T$ <u>and</u> algebra leading to $4\pi^2 R^3 = GMT^2$	**(A1)**
1(c)	$4\pi^2 \times R^3 = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 60 \times 60)^2$ ($R = 4.22 \times 10^7$ m)	**C1**
	$h = R - (6.37 \times 10^6)$	**C1**
	$h = (4.22 \times 10^7) - (6.37 \times 10^6)$ $= 3.6 \times 10^7$ m	**A1**
1(d)(i)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / (24 \times 60 \times 60)$ $= 7.3 \times 10^{-5}$ rad s^{-1}	**A1**
1(d)(ii)	orbit is from east to west	**B1**
	orbit is not equatorial / orbit is polar	**B1**

Question	Answer	Marks
2(a)(i)	(gas that obeys) $pV \propto T$ (for all values of p, V and T)	**M1**
	where T is thermodynamic temperature	**A1**
2(a)(ii)	temperature = –273.15 °C	**A1**
2(b)(i)	$pV = NkT$	**C1**
	$N = (1.37 \times 10^5 \times 0.640) / (1.38 \times 10^{-23} \times (227 + 273))$	**C1**
	$= 1.27 \times 10^{25}$	**A1**
2(b)(ii)	mass $= 0.0424 / (1.27 \times 10^{25})$ $= 3.34 \times 10^{-27}$ kg	**A1**
2(b)(iii)	$\frac{1}{2}m\langle c^2\rangle = (3/2)kT$	**C1**
	$3.34 \times 10^{-27} \times v^2 = 3 \times 1.38 \times 10^{-23} \times 500$	**C1**
	$v = 2490$ m s^{-1}	**A1**
	or	
	$pV = \frac{1}{3}(Nm)\langle c^2\rangle$ <u>and</u> Nm = mass of gas	**(C1)**
	$0.0424 \times v^2 = 3 \times 1.37 \times 10^5 \times 0.640$	**(C1)**
	$v = 2490$ m s^{-1}	**(A1)**
2(c)	sketch: line from (0, 0) to (500, v)	**B1**
	line with decreasing positive gradient throughout	**B1**

Question	Answer	Marks
3(a)	<u>change</u> in internal energy = work done + energy transfer by heating	**C1**
	<u>increase</u> in internal energy = work done <u>on</u> system + energy transferred <u>to</u> the system by heating	**A1**
3(b)(i)	AB change in internal energy: decrease	**B1**
	AB work done on gas: positive	**B1**
	BC change in internal energy: increase	**B1**
	BC work done on gas: zero	**B1**
3(b)(ii)	more work done by gas in CD than is done on gas in AB **or** (no work done on gas in BC and DA so) (overall) gas does work	**B1**
	(overall) change in internal energy is zero	**B1**
	(must be an overall) input of thermal energy	**B1**

Question	Answer	Marks
4(a)(i)	$\omega = 2\pi f$	C1
	$f = 9.7 / 2\pi$ $= 1.5$ Hz	A1
4(a)(ii)	amplitude = $\sqrt{(11.6)}$ = 3.4 cm	A1
4(a)(iii)	$a_0 = \omega^2 x_0$	C1
	$= 9.7^2 \times 3.4 \times 10^{-2}$ $= 3.2\ \text{m s}^{-2}$	A1
4(b)	sketch: straight line through the origin with negative gradient	B1
	line with negative gradient passing through (+3.4, $-a_0$) and (–3.4, $+a_0$)	B1
	line with ends at $x = \pm$ 3.4 cm and $a = \pm a_0$	B1
4(c)	sum of potential energy and kinetic energy is constant	B1
	at maximum displacement, kinetic energy is zero **or** at maximum displacement, potential energy is maximum	B1
	at zero displacement, kinetic energy is maximum **or** at zero displacement, potential energy is minimum	B1

Question	Answer	Marks
5(a)(i)	$Q_A = CV$	**A1**
5(a)(ii)	$E_A = \frac{1}{2}CV^2$	**A1**
5(b)(i)	some of the charge transfers to (the plates of) capacitor B	**B1**
	transfer is because the p.d.s across the capacitors are not equal **or** transfer stops when the p.d.s across the capacitors become equal	**B1**
5(b)(ii)	$V_A = V_B$	**M1**
	charge on A + charge on B = CV	**M1**
	$CV_B + 3CV_B = CV$ leading to $V_B = V / 4$	**A1**
	or	
	$C_T = 4C$	**(M1)**
	$Q_T = CV$	**(M1)**
	$V_B = CV / 4C = V / 4$	**(A1)**
5(b)(iii)	$\Delta E = \frac{1}{2}CV^2 - nCV^2$, where n is a multiple that is less than ½ **or** total final energy $= \frac{1}{2} \times 4C \times (V / 4)^2$ $= \frac{1}{8}CV^2$	**C1**
	$\Delta E = \frac{1}{2}CV^2 - \frac{1}{8}CV^2$ $= \frac{3}{8}CV^2$	**A1**

Question	Answer	Marks
6(a)(i)	product of (magnetic) flux density and area	**M1**
	area perpendicular to the (magnetic) field	**A1**
6(a)(ii)	flux $= B \times \pi r^2$ $= 0.17 \times \pi \times 0.36^2$	**C1**
	$= 6.9 \times 10^{-2}$ Wb	**A1**
6(b)	time for one revolution = 1 / 25 s	**C1**
	e.m.f. = rate of cutting flux **or** $\Delta\Phi / \Delta t$	**C1**
	$= 0.069 \times 25$ = 1.7 V	**A1**
6(c)	current (in disc) is perpendicular to magnetic field **or** current causes force to act on disc	**B1**
	force opposes rotation of disc	**B1**
	left-hand rule indicates current is from rim to axle	**B1**

Question	Answer	Marks
7(a)(i)	full-wave (rectification)	**B1**
7(a)(ii)	lower left diode shown pointing left	**B1**
	lower right and upper left diodes shown pointing left	**B1**
7(a)(iii)	arrow indicating current direction in resistor to the right	**B1**
7(b)(i)	sketch: periodic line showing minimum $V_{OUT} = 0$ and maximum $V_{OUT} = +V_0$	**B1**
	line showing peak V_{OUT} at $t = 0$, $0.5T$, $1.0T$, $1.5T$ and $2.0T$, with V_{OUT} going to zero half-way in between each peak	**B1**
	line showing correct modulated sine shape	**B1**
7(b)(ii)	sketch: sinusoidal curve with troughs sitting on the time axis	**B1**
	<u>peak</u> power at $t = 0$, $0.5T$, $1.0T$, $1.5T$ and $2.0T$ and zero power half-way in between each peak	**B1**
7(b)(iii)	same power-time graph with or without rectification, so same V_{rms} **or** V^2-time graph is same for both V_{OUT} and V_{IN}, so same V_{rms} **or** power does not depend on sign of V, so same V_{rms}	**B1**

Question	Answer	Marks
8(a)	transition (emits) (one) photon with energy equal to the difference in energy between the two levels	**B1**
	frequency of radiation corresponds to energy of photon	**B1**
8(b)(i)	line to the left of the pair in Fig. 8.2, labelled A	**B1**
	larger gap between line A and the nearest of the pair in Fig. 8.2 than between the lines in the pair	**B1**
8(b)(ii)	line to the left of both the pair in Fig. 8.2 and line A, labelled B	**B1**
	larger gap between line B and line A than between line A and the nearest one of the pair in Fig. 8.2	**B1**
8(c)	$E = hf$	**C1**
	$E_3 = E_1 + h(f_A + f_B)$	**A1**

Question	Answer	Marks
9(a)	difference between mass of nucleus and (total) mass of nucleons	**M1**
	when infinitely separated	**A1**
9(b)(i)	neutron	**B1**
9(b)(ii)	$E = \Delta m\, c^2$	**C1**
	Δm = (0.030377 – 0.002388 – 0.009105)u (= 0.018884u)	**C1**
	energy release = (0.030377 – 0.002388 – 0.009105) × 1.66×10^{-27} × $(3.00 \times 10^8)^2$ = 2.8×10^{-12} J	**A1**
9(c)(i)	number of atoms per unit time = $(1.4 \times 10^{28}) / (2.8 \times 10^{-12})$ (= 5.0×10^{39} s^{-1})	**C1**
	mass of one atom = $4 \times 1.66 \times 10^{-27}$ or $(4 \times 10^{-3}) / (6.02 \times 10^{23})$ (= 6.64×10^{-27} kg)	**C1**
	mass per unit time = $6.64 \times 10^{-27} \times 5.0 \times 10^{39}$ = 3.3×10^{13} kg s^{-1}	**A1**
9(c)(ii)	$L = 4\pi\sigma r^2 T^4$ $1.4 \times 10^{28} = 4\pi \times 5.67 \times 10^{-8} \times (2.3 \times 10^9)^2 \times T^4$	**C1**
	T = 7800 K	**A1**

Question	Answer	Marks
10(a)(i)	electrons	**B1**
10(a)(ii)	electrons are decelerated / stopped on impact with the target	**B1**
	(kinetic) energy lost by electrons emitted as (X-ray) photons	**B1**
10(a)(iii)	$eV = hc / \lambda$	**C1**
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (1.60 \times 10^{-19} \times 5800)$	**C1**
	$= 2.14 \times 10^{-10}$ m	**A1**
10(b)	$I = I_0 \exp(-\mu x)$	**C1**
	$I_T / I_0 = \exp(-(1.4 \times 2.8))$ $= 0.020$	**C1**
	% absorbed $= (1.000 - 0.0198) \times 100$ $= 98\%$	**A1**

Cambridge International AS & A Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 2022**

MARK SCHEME

Maximum Mark: 100

Published

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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	<u>‘List rule’ guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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. Within 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)(i)	work (done) per unit mass	**B1**
	work (done on mass) in moving mass from infinity (to the point)	**B1**
1(a)(ii)	$E_P = \phi m$ $E_P = (- GM / r) \times m = - GMm / r$ **or** $\phi = - GM / r$ **and** $E_P = \phi m = - GMm / r$	**B1**
1(b)(i)	$\Delta E_P = 6.67 \times 10^{-11} \times 1.99 \times 10^{30} \times 2.20 \times 10^{14} \times [1 / (6.38 \times 10^{10}) - 1 / (8.44 \times 10^{11})]$	**C1**
	$= 4.23 \times 10^{23}$ J	**A1**
1(b)(ii)	(gravitational) force is attractive so decrease **or** (gravitational) force does work so decrease	**B1**
1(b)(iii)	$\Delta E_P = ½m(v_2^2 - v_1^2)$	**C1**
	$4.23 \times 10^{23} = ½ \times 2.20 \times 10^{14} \times (v^2 - 34\,100^2)$	**C1**
	v (= 70 800 m s^{-1}) = 70.8 km s^{-1}	**A1**
1(c)	both PE and KE equations include m, so path is unchanged	**B1**

Question	Answer	Marks
2(a)	(electric) force is (directly) proportional to product of charges	**B1**
	force (between point charges) is inversely proportional to the square of their separation	**B1**
2(b)(i)	(electric) force is perpendicular to velocity (of particles)	**B1**
	force (perpendicular to velocity) causes centripetal acceleration **or** force does not change the speed of the particles **or** force has constant magnitude	**B1**
2(b)(ii)	$F = e^2 / 4\pi\varepsilon_0 x^2$	**C1**
	$= (1.60 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (2 \times 1.59 \times 10^{-10})^2]$ $= 2.28 \times 10^{-9}$ N	**A1**
2(b)(iii)	$F = mr\omega^2$ **and** $\omega = 2\pi / T$ **or** $F = mv^2 / r$ **<u>and</u>** $v = 2\pi r / T$	**C1**
	$F = 4\pi^2 mr / T^2$ $T = \sqrt{[4\pi^2 \times 9.11 \times 10^{-31} \times 1.59 \times 10^{-10} / (2.28 \times 10^{-9})]}$	**C1**
	$= 1.58 \times 10^{-15}$ s	**A1**
2(c)(i)	• electron and positron interact • positron is anti-particle of electron • (pair) annihilation occurs *Any two points, 1 mark each*	**B2**
	mass of the electron and positron converted into photon energy	**B1**
2(c)(ii)	PET scanning	**B1**

Question	Answer	Marks
3(a)	(thermal) energy per unit mass	**B1**
	energy to change state between liquid and gas at constant temperature	**B1**
3(b)(i)	$q = mL = 0.37 \times 2.3 \times 10^6$ $= 8.5 \times 10^5$ J	**A1**
3(b)(ii)	$pV = nRT$ **and** $T = 373$ K	**C1**
	$n = 370 / 18$	**C1**
	$V = [(370 / 18) \times 8.31 \times 373] / (1.0 \times 10^5) = 0.64$ m^3	**A1**
3(b)(iii)	$w = p\Delta V$	**C1**
	$= 1.0 \times 10^5 \times 0.64$ $= 6.4 \times 10^4$ J	**A1**
3(b)(iv)	(water does work against atmosphere so) work done on water is negative	**B1**
	increase in internal energy = $(8.5 – 0.64) \times 10^5 = 7.9 \times 10^5$ J	**A1**
3(c)	valid reasoning of how work done by water is affected	**M1**
	correct use of first law to draw conclusion about effect on specific latent heat that is consistent with work done	**A1**

Question	Answer	Marks
4(a)	oscillations (of object) at maximum amplitude	**B1**
	when driving frequency equals natural frequency (of object)	**B1**
4(b)(i)	$T = 2\pi / \omega$	**C1**
	$= 2\pi / 5.0\pi$ $= 0.40$ s	**A1**
4(b)(ii)	displacement scale labelled –1.0, –0.5, (0), 0.5, 1.0 on the 2 cm tick marks	**B1**
	t scale labelled 0.2, 0.4, 0.6, 0.8, 1.0, 1.2 on the 2 cm tick marks	**B1**
4(b)(iii)	$\phi = 2\pi\Delta t / T$ $= 2\pi \times 0.10 / 0.40$ **or** $2\pi \times 0.30 / 0.40$	**C1**
	$= 1.6$ rad **or** 4.7 rad	**A1**

Question	Answer	Marks
5(a)	charge / potential (difference)	M1
	charge is charge on one plate, <u>and</u> potential is p.d. across the plates	A1
5(b)	p.d. across both capacitors = E	B1
	$Q_T = Q_1 + Q_2$	B1
	$C_TE = C_1E + C_2E$ hence $C_T = C_1 + C_2$	B1
5(c)(i)	$[(1/22) + (1/47)]^{-1} = 15\ \mu F$	A1
5(c)(ii)	energy = $\frac{1}{2}CV^2$	C1
	$= \frac{1}{2} \times 15 \times 10^{-6} \times 12^2$ $= 1.1 \times 10^{-3}$ J	A1
5(c)(iii)	initial p.d. (across 22 μF) $= 12 \times (15/22)$ $= 8.2$ V **or** final p.d. across both capacitors $= 6.0 \times (22/15)$ $= 8.8$ V	C1
	$V = V_0 \exp[-t/(2.7 \times 10^6 \times 15 \times 10^{-6})]$	C1
	$6.0 = 8.2 \exp[-t/(2.7 \times 10^6 \times 15 \times 10^{-6})]$ **or** $8.8 = 12 \exp[-t/(2.7 \times 10^6 \times 15 \times 10^{-6})]$ $t = 13$ s	A1

Question	Answer	Marks
6(a)	there must be a current (in the wire)	**B1**
	(wire) must be at a non-zero angle to the magnetic field	**B1**
6(b)(i)	arrow from X pointing horizontally to the left	**B1**
	arrow from Y pointing diagonally upwards and to the left at about 45°	**B1**
	arrow from Z pointing horizontally to the right	**B1**
6(b)(ii)	(flux densities at W and X are approximately) equal	**B1**
	(flux density at) Y greater than (flux density at) Z	**B1**
6(c)	current in wire creates magnetic field around wire	**B1**
	(each) wire sits in the magnetic field created by the other	**B1**
	(for each wire,) current / wire is perpendicular to magnetic field (due to other wire), (so) experiences a (magnetic) force	**B1**

Question	Answer	Marks
7(a)	induced e.m.f. is (directly) proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
7(b)	V_2 stepped, all at non-zero values, between t = 0 and t = 0.40 s	**B1**
	V_2 shown with same non-zero magnitude up to t = 0.15 s and after t = 0.25 s but with a different magnitude between these times	**B1**
	V_2 shown with a magnitude between t = 0.15 s and t = 0.25 s that is three times the magnitude before t = 0.15 s and after t = 0.25 s	**B1**
	V_2 shown with same sign up to t = 0.15 s and after t = 0.25 s, and opposite sign in between	**B1**
7(c)(i)	changing current in coil causes changing (magnetic) field **or** changing (magnetic) flux causes induced e.m.f. in ring	**B1**
	induced e.m.f. in ring causes current in ring	**B1**
	(magnetic) field due to (induced) current in ring interacts with (coil's) field to cause upwards force (on ring) **or** (induced) current in ring perpendicular to (coil's magnetic) field causes upwards force (on ring)	**B1**
7(c)(ii)	both magnetic fields reverse direction so ring still jumps up **or** current (in ring) and (coil's) field both reverse so ring still jumps up	**B1**

Question	Answer	Marks
8(a)(i)	photoelectric effect	**B1**
8(a)(ii)	electron diffraction	**B1**
8(b)(i)	$\lambda = h / p$	**C1**
	$p = 4 \times 1.66 \times 10^{-27} \times 6.2 \times 10^{7}$ ($= 4.1 \times 10^{-19}$ N s)	**C1**
	$\lambda = 6.63 \times 10^{-34} / 4.1 \times 10^{-19}$ $= 1.6 \times 10^{-15}$ m	**A1**
8(b)(ii)	line with negative gradient throughout	**B1**
	curve asymptotic to both axes with non-zero λ at $v = 6.2 \times 10^{7}$ m s^{-1}	**B1**
8(c)	(de Broglie) wavelength negligible compared with width of doorway	**B1**

Question	Answer	Marks
9(a)(i)	speed is (directly) proportional to distance	**M1**
	where speed is speed of recession of galaxy (from observer) and distance is distance of galaxy away from observer	**A1**
9(a)(ii)	wavelengths (of spectral lines) are greater (than their known values)	**B1**
	redshift shows stars (in distant galaxies) moving away from Earth	**B1**
9(b)	(all) parts of Universe moving away from each other	**B1**
	more distant objects are moving away faster	**B1**
	matter must have been close together / very dense in the past	**B1**

Question	Answer	Marks
10(a)	spontaneous emission of (ionising) radiation	**B1**
	emission from unstable nucleus	**B1**
10(b)(i)	curve with decreasing negative gradient passing through $(0, N_0)$	**B1**
	curve passing through $(T, 0.5N_0)$	**B1**
	curve passing through $(2T, 0.25N_0)$ **and** $(3T, 0.125N_0)$	**B1**
10(b)(ii)	line through origin with positive gradient	**B1**
	straight line passing through (N_0, A_0)	**B1**
10(c)(i)	activity	**B1**
10(c)(ii)	decay constant	**B1**
10(d)	$N = N_0 \exp(-\ln 2 \times 1.70T / T)$	**C1**
	$N / N_0 = 0.31$	**A1**

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 2017**

MARK SCHEME

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Question	Answer	Marks
1(a)	force per unit mass	B1
1(b)(i)	$g = GM / r^2$ $= (6.67 \times 10^{-11} \times 1.0 \times 10^{13}) / (3.6 \times 10^3)^2$	C1
	$= 5.1 \times 10^{-5}$ N kg^{-1}	A1
1(b)(ii)	mass = (960 / 9.81) kg weight on comet $= (960 / 9.81) \times 5.1 \times 10^{-5}$	C1
	$= 5.0 \times 10^{-3}$ N	A1
1(c)	similarity: e.g. both attractive/pointed towards the comet e.g. same order of magnitude	B1
	difference: e.g. radial/non-radial e.g. same (over surface)/varies (over surface)	B1

Question	Answer	Marks
2(a)(i)	mean/average square speed/velocity	**B1**
2(a)(ii)	$pV = NkT$ **or** $pV = nRT$	**B1**
	$\rho = Nm / V$ **or** $\rho = nN_Am / V$ **and** $k = nR / N$	**B1**
	$E_K = ½\, m\langle c^2\rangle$ with algebra to $(3/2)kT$	**B1**
2(b)(i)	no (external) work done **or** $\Delta U = q$ **or** $w = 0$	**B1**
	$q = N_A \times (3/2)k \times 1.0$	**M1**
	$N_Ak = R$ so $q = (3/2)R$	**A1**
2(b)(ii)	specific heat capacity = $\{(3/2) \times R\} / 0.028$	**C1**
	= 450 J kg^{-1} K^{-1}	**A1**

Question	Answer	Marks
3(a)(i)	e.g. period = 6 / 2.5	**C1**
	frequency = 0.42 Hz	**A1**
3(a)(ii)	energy $= \frac{1}{2} m \times 4\pi^2 f^2 y_0^2$	**C1**
	$= \frac{1}{2} \times 0.25 \times 4\pi^2 \times 0.42^2 \times (1.5 \times 10^{-2})^2$	**C1**
	$= 2.0 \times 10^{-4}$ J	**A1**
3(b)(i)	(induced) e.m.f. proportional to rate of	**M1**
	change of magnetic flux (linkage) **or** cutting of magnetic flux	**A1**
3(b)(ii)	coil cuts flux/field (of moving magnet) inducing e.m.f. in coil	**B1**
	(induced) current in resistor causes heating (effect)	**M1**
	thermal energy/heat derived from energy of oscillations (of magnet)	**A1**

Question	Answer	Marks
4(a)	pulse (of ultrasound)	**B1**
	* produced by quartz crystal/piezo-electric crystal	
	* gel/coupling medium (on skin) used to reduce reflection at skin	
	reflected from boundaries (between media)	**B1**
	reflected pulse/wave detected by (ultrasound) transmitter	**B1**
	reflected wave processed and displayed	**B1**
	* intensity of reflected pulse/wave gives information about boundary	
	* time delay gives information about depth of boundary	
	max. 2 of additional detail points marked *	**B2**
4(b)	$I_T = I_0 \exp(-\mu x)$	**C1**
	$2.9 = \exp(4.6\mu)$	**C1**
	$\mu = 0.23\,\text{cm}^{-1}$	**A1**

Question	Answer	Marks
5(a)	any two reasonable suggestions e.g. • signal can be regenerated/noise removed (not "no noise") • circuits more reliable • circuits cheaper to produce • multiplexing (is possible) • error correction/checking • easier encryption/better security	**B2**
5(b)(i)	samples the analogue signal	**M1**
	at regular intervals and converts it (to a digital number)	**A1**
5(b)(ii)	**1.** smaller step depth	**B1**
	2. smaller step height	**B1**

Question	Answer	Marks
6(a)	force proportional to product of charges and inversely proportional to the square of the separation	**M1**
	reference to point charges	**A1**
6(b)(i)	(near to each sphere,) fields are in opposite directions **or** point (between spheres) where fields are equal and opposite **or** point (between spheres) where field strength is zero	**M1**
	so same (sign of charge)	**A1**
6(b)(ii)	(at x = 5.0 cm,) $E = 3.0 \times 10^{3}$ V m^{-1} **and** $a = qE / m$	**C1**
	$E = (1.60 \times 10^{-19} \times 3.0 \times 10^{3}) / (1.67 \times 10^{-27})$	**C1**
	$= 2.9 \times 10^{11}$ m s^{-2}	**A1**
6(c)	field strength or E is potential gradient **or** field strength is rate of change of (electric) potential	**M1**
	(field strength) maximum at x = 6 cm	**A1**

Question	Answer	Marks
7(a)	equal and opposite charges on the plates so no resultant charge	**B1**
	+ve and –ve charges separated so energy stored	**B1**
7(b)	charge / potential difference	**M1**
	reference to charge on one plate and p.d. between plates	**A1**
7(c)	energy = ½ CV^2 **or** energy = ½ QV **and** $C = Q / V$	**C1**
	$(1 / 16) \times ½ CV_0^2 = ½ CV^2$ $V = ¼ V_0$	**A1**

Question	Answer	Marks
8(a)(i)	circle around both diodes	**B1**
8(a)(ii)	indicates (whether) temperature	**M1**
	(is) above or below a set value	**A1**
8(b)(i)	(when resistance of C > R_V,) $V^- > V^+$ **or** $V^+ < 3\,V$ **or** p.d. across R_V < p.d. across R/Y/3 V **or** p.d. across C > p.d. across R/ X/3 V	**M1**
	op-amp output is negative	**M1**
	(only) green	**A1**
8(b)(ii)	resistance of C becomes less than R_V **or** $V^- < V^+$	**B1**
	green (LED) goes out	**A1**
	blue (LED) comes on	**A1**
8(c)	changes/determines <u>temperature</u> at which LEDs switch	**B1**

Question	Answer	Marks
9(a)(i)	Hall voltage depends on thickness of slice	**C1**
	thinner slice, larger Hall voltage	**A1**
9(a)(ii)	Hall voltage depends on current in slice	**B1**
9(b)	sinusoidal wave, one cycle	**B1**
	at $\theta = 0$ and at $\theta = 360°$, $V_H = V_{MAX}$	**B1**
	at $\theta = 180°$, $V_H = -V_{MAX}$	**B1**

Question	Answer	Marks
10(a)	two from: • frequency below which electrons not ejected • <u>maximum</u> energy of electron depends on frequency • <u>maximum</u> energy of electrons does not depend on intensity • instantaneous emission of electrons	**B2**
10(b)(i)	(λ_0 is the) threshold wavelength **or** wavelength corresponding to threshold frequency **or** maximum wavelength for emission of electrons	**B1**
10(b)(ii)1.	intercept = $1/\lambda_0 = 2.2 \times 10^6\,\text{m}^{-1}$ $\lambda_0 = 4.5 \times 10^{-7}$ m or 450 nm	**A1**
10(b)(ii)2.	gradient = hc	**C1**
	gradient = 2.0×10^{-25} or correct substitution into gradient formula	**C1**
	$h = (2.0 \times 10^{-25}) / (3.0 \times 10^8) = 6.7 \times 10^{-34}$ J s	**A1**
10(c)	line: same gradient	**B1**
	straight line, positive gradient, intercept at greater than 2.2×10^6 when candidate's line extrapolated	**B1**

Question	Answer	Marks
11(a)	loss of (electric) potential energy = gain in kinetic energy **or** $qV = ½mv^2$ **or** $E_K = p^2 / 2m = qV$	**B1**
	$p = mv$ with algebra leading to $p = \sqrt{(2mqV)}$	**B1**
11(b)(i)	particle/electron has a wavelength (associated with it)	**B1**
	dependent on its momentum **or** when/because particle is moving	**B1**
11(b)(ii)	$p = (2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2}$	**C1**
	$\lambda = (6.63 \times 10^{-34}) / (5.91 \times 10^{-24})$	**C1**
	$= 1.12 \times 10^{-10}$ m	**A1**
11(c)	wavelength is similar to separation of atoms	**M1**
	so diffraction observed	**A1**

Question	Answer	Marks
12(a)	$7\,{}^{0}_{-1}\text{e}$	**A1**
12(b)(i)	$E = mc^2$	**C1**
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	**M1**
	$= 1.494 \times 10^{-10}$ J division by 1.60×10^{-13} clear to give 934 MeV	**A1**
12(b)(ii)	Δm = (82 × 1.00863u) + (57 × 1.00728u) – 138.955u = (–) 1.16762 (u)	**C1**
	energy = 1.16762 × 934	**C1**
	energy per nucleon = (1.16762 × 934) / 139 = 7.85 MeV	**A1**
12(c)	above A = 56, binding energy per nucleon decreases as A increases	**B1**
	U-235 has larger nucleon number	**M1**
	so less (binding energy per nucleon)	**A1**
	or	
	fission takes place with uranium	**(B1)**
	fission reaction releases energy	**(M1)**
	binding energy per nucleon less (for uranium than for products)	**(A1)**

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **May/June 2017**

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.

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Question	Answer	Marks
1(a)	gravitational force (of attraction between satellite and planet)	**B1**
	provides / is centripetal force (on satellite about the planet)	**B1**
1(b)	$M = (4/3) \times \pi R^3 \rho$	**B1**
	$\omega = 2\pi / T$ **or** $v = 2\pi nR / T$	**B1**
	$GM / (nR)^2 = nR\omega^2$ **or** v^2 / nR	**M1**
	substitution clear to give $\rho = 3\pi n^3 / GT^2$	**A1**
1(c)	$n = (3.84 \times 10^5) / (6.38 \times 10^3) = 60.19$ or 60.2	**C1**
	$\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$	**C1**
	$\rho = 5.54 \times 10^3\ \text{kg m}^{-3}$	**A1**

Question	Answer	Marks
2(a)	e.g. period = 3 / 2.5	**C1**
	frequency = 0.83 Hz	**A1**
2(b)	light (damping)	**B1**
2(c)	at 2.7 s, A_0 = 1.5 (cm)	**B1**
	energy = $\frac{1}{2} m \times 4\pi^2 f^2 A_0^2$	**B1**
	$= \frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$ $= 5.51 \times 10^{-4}$ (J)	**C1**
	at 7.5 s, A_0 = 0.75 (cm)	**B1**
	energy = $\frac{1}{4} \times 5.51 \times 10^{-4}$ **or** energy = $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	**C1**
	energy = 1.38×10^{-4} (J) change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	**A1**

Question	Answer	Marks
3(a)(i)	signal consists of (a series of) 1s and 0s **or** offs and ons **or** highs and lows	**B1**
3(a)(ii)	component X: parallel-to-serial converter	**B1**
	component Y: DAC/digital-to-analogue converter	**B1**
3(a)(iii)	sample the (analogue) signal	**M1**
	at regular intervals and converts the analogue number to a digital number	**A1**
3(b)(i)	attenuation in fibre = 84 × 0.19 (= 16 dB)	**C1**
	ratio = 16 + 28 = 44 dB	**A1**
3(b)(ii)	ratio / dB = 10 lg (P_2 / P_1)	**C1**
	44 = 10 lg ({9.7×10^{-3}} / P) **or** –44 = 10 lg (P / {9.7×10^{-3}})	**C1**
	power = 3.9×10^{-7} W	**A1**

Question	Answer	Marks
4(a)	random/haphazard	**B1**
	constant velocity **or** speed in a straight line between collisions **or** distribution of speeds/different directions	**B1**
4(b)	(small) specks of light/bright specks/pollen grains/dust particles/smoke particles	**M1**
	moving haphazardly/randomly/jerky/in a zigzag fashion	**A1**
4(c)(i)	$pV = \frac{1}{3} Nm\langle c^2\rangle$ $1.05 \times 10^5 \times 0.0240 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	**C1**
	$\langle c^2\rangle = 1.89 \times 10^6$	**C1**
	or	
	$\frac{1}{2} m\langle c^2\rangle = (3/2)\,kT$ $0.5 \times (4.00 \times 10^{-3} / 6.02 \times 10^{23}) \times \langle c^2\rangle = 1.5 \times 1.38 \times 10^{-23} \times 300$	**(C1)**
	$\langle c^2\rangle = 1.87 \times 10^6$	**(C1)**
	or	
	$nRT = \frac{1}{3} Nm\langle c^2\rangle$ $1.00 \times 8.31 \times 300 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	**(C1)**
	$\langle c^2\rangle = 1.87 \times 10^6$	**(C1)**
	$c_{\text{r.m.s.}} = 1.37 \times 10^3\ \text{m s}^{-1}$	**A1**

Question	Answer	Marks
4(c)(ii)	$\langle c^2 \rangle \propto T$	C1
	$\langle c^2 \rangle$ at 177 °C = $1.89 \times 10^6 \times (450 / 300)$	C1
	$c_{r.m.s.}$ at 177 °C = 1.68×10^3 m s^{-1}	A1

Question	Answer	Marks
5(a)	(loss in) kinetic energy of α-particle = $Qq / 4\pi\varepsilon_0 r$ **or** $7.7 \times 10^{-13} = Qq / 4\pi\varepsilon_0 r$	C1
	$7.7 \times 10^{-13} = 8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / r$	M1
	$r = 4.7 \times 10^{-14}$ m r is closest distance of approach so radius less than this	A1
5(b)	force = $Qq / 4\pi\varepsilon_0 r^2 = 4\text{u} \times a$	C1
	$8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / (4.7 \times 10^{-14})^2 = 4 \times 1.66 \times 10^{-27} \times a$	C1
	$a = 2.5 \times 10^{27}$ m s^{-2}	A1
5(c)	so that single interactions between nucleus and α-particle can be studied **or** so that multiple deflections with nucleus do not occur	B1

Question	Answer	Marks
6(a)(i)	lamp needs 'high' power/'large' current/'large' voltage	**B1**
	op-amp can deliver only a small current/small voltage	**B1**
6(a)(ii)	correct symbol for relay coil connected between output and earth	**B1**
	switch between mains supply and lamp	**B1**
6(b)(i)	vary light intensity at which lamp is switched on/off	**B1**
6(b)(ii)	so that relay operates for only one current/voltage direction **or** so that relay/lamp operates for either dark or light conditions	**B1**
6(c)	when light level increases, LDR resistance decreases	**B1**
	(R_{LDR} low,) so $V^- > V^+$, so V_{OUT} negative/–5 V (must be consistent with B1 mark)	**M1**
	or	
	when light level decreases, LDR resistance increases	**(B1)**
	(R_{LDR} high,) so $V^- < V^+$, so V_{OUT} is positive/+5 V (must be consistent with B1 mark)	**(M1)**
	lamp comes on as light level decreases **or** lamp goes off as light level increases	**A1**

Question	Answer	Marks
7(a)	(magnetic) force (always) normal to velocity/direction of motion	**M1**
	(magnitude of magnetic) force constant **or** speed is constant/kinetic energy is constant	**M1**
	so provides the centripetal force	**A1**
7(b)	increase in KE = loss in PE **or** $\frac{1}{2} mv^2 = qV$	**M1**
	$p = mv$ with algebra leading to $p = \sqrt{(2mqV)}$	**A1**
7(c)	$Bqv = mv^2 / r$ $mv = Bqr$ **or** $p = Bqr$	**C1**
	$(2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2} = B \times 1.60 \times 10^{-19} \times 0.074$	**C1**
	$B = 5.0 \times 10^{-4}$ T	**A1**
7(d)	greater momentum	**M1**
	($p = Bqr$ and) so r increased	**A1**

Question	Answer	Marks
8	strong (uniform) magnetic field	**B1**
	* nuclei precess/rotate about field (direction)	
	radio frequency pulse/RF pulse (applied)	**B1**
	* RF or pulse is at Larmor frequency / frequency of precession	
	causes resonance / excitation (of nuclei)/nuclei to absorb energy	**B1**
	on relaxation/de-excitation, nuclei emit RF/pulse	**B1**
	* (emitted) RF/pulse detected and processed	
	non-uniform field (superposed on uniform field)	**B1**
	allows positions of (resonating) nuclei to be determined	**B1**
	* allows for position of detection to be changed/different slices to be studied	
	*max. 2 of additional detail points marked **	**B2**

Question	Answer	Marks
9(a)(i)	core reduces loss of (magnetic) flux linkage/improves flux linkage	**B1**
9(a)(ii)	reduces (size of eddy) currents in core	**B1**
	(so that) heating of core is reduced	**B1**
9(b)	alternating voltage gives rise to changing magnetic flux in core	**M1**
	(changing) flux links the secondary coil	**A1**
	induced e.m.f. (in secondary) only when flux is changing/cut	**B1**

Question	Answer	Marks
10(a)(i)	penetration of beam	**M1**
	greater hardness means greater penetration/shorter wavelength/higher frequency/higher photon energy	**A1**
10(a)(ii)	greater accelerating potential difference **or** greater p.d. between anode and cathode	**B1**
10(b)	$I = I_0 \exp(-\mu x)$ ratio = (exp {–1.5 × 2.9}) / (exp {–4.0 × 0.95}) (= exp {–0.55})	**C1**
	= 0.58	**A1**

Question	Answer	Marks
11(a)	electrons (in gas atoms/molecules) interact with photons	**B1**
	photon energy causes electron to move to higher energy level/to be excited	**B1**
	photon energy = difference in energy of (electron) energy levels	**B1**
	when electrons de-excite, photons emitted in all directions (so dark line)	**B1**
11(b)(i)	photon energy $\propto 1 / \lambda$	**C1**
	energy = 1.68 eV	**A1**
	or	
	$E = hc / \lambda$ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / (740 \times 10^{-9})$ $= 2.688 \times 10^{-19}$ J	**(C1)**
	energy = 1.68 eV	**(A1)**
11(b)(ii)	3.4 eV → 1.5 eV 3.4 eV → 0.85 eV 3.4 eV → 0.54 eV *all correct and none incorrect 2/2* *2 correct and 1 incorrect or only 2 correctly drawn 1/2*	**B2**

Question	Answer	Marks
12(a)	$x = 7$	A1
12(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $= 1.494 \times 10^{-10}$ J	C1
	division by 1.6×10^{-13} clear to give 934 MeV	A1
12(b)(ii)	$\Delta m = (235.123 + 1.00863) – (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ **or** $\Delta m = 235.123 – (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	C1
	$= 0.21053$ u	C1
	energy $= 0.21053 \times 934$ $= 197$ MeV	A1
12(c)	kinetic energy of nuclei/particles/products/fragments	B1
	γ–ray photon energy	B1

Cambridge International AS & A Level

PHYSICS	**9702/41**
Paper 4 A Level Structured Questions	**May/June 2022**
MARK SCHEME	
Maximum Mark: 100	

Published

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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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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. Within 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)(i)	(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(a)(ii)	$g = F / m$	**C1**
	$F = GMm / r^2$ and so $g = [GMm / r^2] / m = GM / r^2$	**A1**
1(b)(i)	$g = (6.67 \times 10^{-11} \times 7.35 \times 10^{22}) / (1.74 \times 10^6)^2 = 1.62\ \text{N kg}^{-1}$	**A1**
1(b)(ii)	fields (due to Earth and the Moon) have equal magnitudes	**B1**
	fields (due to Earth and the Moon) are in opposite directions	**B1**
1(b)(iii)	distance of X from Earth = $(3.84 \times 10^8 - x)$	**C1**
	$(G \times)\ 7.35 \times 10^{22} / x^2 = (G \times)\ 5.98 \times 10^{24} / (3.84 \times 10^8 - x)^2$	**C1**
	$x = 3.8 \times 10^7$ m	**A1**

Question	Answer	Marks
2(a)(i)	(vertically) downwards	**B1**
2(a)(ii)	magnetic force (on sphere) is perpendicular to its velocity	**B1**
	magnetic force perpendicular to velocity is the centripetal force **or** magnetic force perpendicular to velocity causes centripetal acceleration **or** acceleration perpendicular to velocity is centripetal (acceleration) **or** magnetic force does not change the speed of the sphere **or** magnetic force has constant magnitude	**B1**
2(b)	$mg = Eq$	**C1**
	$E = (1.6 \times 10^{-10} \times 9.81) / (0.27 \times 10^{-9})$ $= 5.8\ \text{N C}^{-1}$	**A1**
2(c)	centripetal force = magnetic force **or** $Bqv = mv^2 / r$	**B1**
	$B = mv / qr$	**C1**
	$= (1.6 \times 10^{-10} \times 0.78) / (0.27 \times 10^{-9} \times 3.4) = 0.14\ \text{T}$	**A1**

Question	Answer	Marks
3(a)(i)	a gas that obeys $pV \propto T$	**M1**
	where p = pressure, V = volume, T = thermodynamic temperature	**A1**
3(a)(ii)	$T = (273 + 17)\,\text{K}$	**C1**
	$n = pV / RT$ $= (1.2 \times 10^5 \times 0.24) / [8.31 \times (273 + 17)]$ $= 12\,\text{mol}$	**A1**
3(b)(i)	work done $= p\Delta V$	**C1**
	$= 1.2 \times 10^5 \times (0.24 - 0.08) = 19200\,\text{J}$ (= 19.2 kJ)	**A1**
3(b)(ii)	AB work done correct (19.2)	**A1**
	BC work done correct (0)	**A1**
	CA increase in internal energy correct (0) **and** CA thermal energy correct (31.6)	**A1**
	AB increase in internal energy calculated correctly from work done – 48.0	**A1**
	BC increase in internal energy correctly calculated so the final column adds up to zero **and** BC thermal energy same as increase in internal energy (Fully correct table: AB | 19.2 | –48.0 | –28.8 BC | 0 | 28.8 | 28.8 CA | –31.6 | 31.6 | 0)	**A1**

Question	Answer	Marks
4(a)	straight line through origin shows that *a* is proportional to *x*	B1
	negative gradient shows that *a* is in opposite direction to *x*	B1
4(b)(i)	$a_0 = \omega^2 x_0$ **or** $a = -\omega^2 x$ **or** $\omega^2 = -$ gradient	C1
	$\omega = \sqrt{(0.40 / 0.050)}$ $= 2.8\ \text{rad s}^{-1}$	A1
4(b)(ii)	$k = \omega^2 L$ $= 2.8^2 \times 1.24$	C1
	$= 9.7\ \text{m s}^{-2}$	A1
4(c)	(increasing *L* causes) ω to decrease **or** energy (= ½ $m\omega^2 x_0^2$) = ½ mkx_0^2 / L (and *L* increases)	M1
	so amplitude increases	A1

Question	Answer	Marks
5(a)(i)	conversion (from a.c.) to d.c.	**B1**
5(a)(ii)	full-wave (rectification)	**B1**
5(b)(i)	P labelled – **and** Q labelled +	**B1**
5(b)(ii)	V_{OUT} scale labelled 4 and 8 on the 2 cm tick marks	**B1**
	$T = 2\pi / \omega$ $= 2\pi / 25\pi$ $= 0.08$ s	**C1**
	t scale labelled 0.02, 0.04, 0.06, 0.08, 0.10, 0.12 on the 2 cm tick marks	**A1**
5(c)(i)	correct symbol used for capacitor and capacitor connected in parallel with the 1.2 kΩ resistor.	**B1**
5(c)(ii)	straight lines or curves, with negative decreasing gradients, drawn between adjacent peaks, from top of first peak to meet line going up to next peak	**B1**
	lines, from one peak to the line going up to the next peak, show a drop in p.d. of 1½ small squares	**B1**
5(c)(iii)	$V = 0.90 \times 6.0$ (= 5.4 V) **or** discharge time (for each cycle) = 0.034 s	**C1**
	$V = V_0 \exp(-t / RC)$ $5.4 = 6.0 \exp[-0.034 / (1.2 \times 10^3 \times C)]$	**C1**
	$C = 2.7 \times 10^{-4}$ F	**A1**

Question	Answer	Marks
6(a)	product of (magnetic) flux density and area	**M1**
	where area is perpendicular to the (magnetic) field	**A1**
6(b)(i)	$N\Phi = BAN$	**C1**
	$= 400 \times 10^{-3} \times 0.12^2 \times 8$	**C1**
	$= 0.046$ Wb	**A1**
6(b)(ii)	(line is a) straight line	**B1**
6(b)(iii)	(induced) e.m.f. = rate of change of flux linkage	**C1**
	e.m.f. $= N\Phi / t$ $= 0.046 / 0.60$ $= 0.077$ V	**A1**
6(c)	(induced e.m.f. causes) current flow (in the coil)	**B1**
	either	
	current (in magnetic field) causes forces to act on the coil	**B1**
	(opposite sides of) coil forced inwards	**B1**
	or	
	current causes dissipation of energy in the resistance of the coil	**(B1)**
	temperature of the coil rises	**(B1)**

Question	Answer	Marks
7(a)	quantum of energy	**M1**
	of electromagnetic radiation	**A1**
7(b)(i)	photoelectric effect	**B1**
7(b)(ii)	• there is a frequency below which no electrons are emitted **or** threshold frequency = 5.4×10^{14} Hz • work function of the metal = 3.6×10^{-19} J (or 2.2 eV) • E_{MAX} increases (linearly) with (increasing) frequency • gradient of the line is the Planck constant **or** gradient of the line is 6.7×10^{-34} J s *Any three bullet points, 1 mark each*	**B3**
7(c)(i)	different threshold frequency	**B1**
	(line has) same gradient but different intercept	**B1**
7(c)(ii)	photons have same energy	**B1**
	line unchanged	**B1**

Question	Answer	Marks
8(a)(i)	energy required to separate the nucleons (in the nucleus)	**M1**
	to infinity	**A1**
8(a)(ii)	curve starting close to the origin and forming a single peak	**B1**
	peak shown to left of centre, with steep line on LHS of peak and shallow line on RHS of peak	**B1**
8(b)(i)	fusion	**B1**
8(b)(ii)	both particles have low *A* values **or** both particles are at left-hand end of graph	**B1**
	He-3 has higher binding energy (per nucleon) than H-2	**B1**
8(c)	$\Delta m = [(2 \times 2.014102) - (3.016029 + 1.008665)]$ u $(= 0.00351$ u$)$	**C1**
	$E = \Delta mc^2$	**C1**
	$= 0.00351 \times 1.66 \times 10^{-27} \times (3.00 \times 10^{8})^2$ $(= 5.24 \times 10^{-13}$ J$)$	**C1**
	1.00 mol of deuterium forms 0.500 mol of helium-3	**C1**
	total energy $= 0.500 \times 6.02 \times 10^{23} \times 5.24 \times 10^{-13}$ $= 1.58 \times 10^{11}$ J	**A1**

Question	Answer	Marks
9(a)(i)	electrons are accelerated (by an applied p.d.)	**B1**
	electrons hit target	**B1**
	X-rays produced when electrons decelerate	**B1**
9(a)(ii)	images of the multiple sections are combined to create a 3-D image	**B1**
9(b)(i)	$I = I_0 \exp(-\mu x)$	**C1**
	$= I_0 \exp(-0.89 \times 5.6)$ $= 0.0068\, I_0$	**A1**
9(b)(ii)	$I = I_0 \exp(-2.4 \times 3.4) \times \exp(-0.89 \times 3.2)$	**C1**
	$= 1.7 \times 10^{-5}\, I_0$	**A1**
9(c)	comparison of intensities or values in **(b)** leading to conclusion consistent with these values	**B1**

Question	Answer	Marks
10(a)	wavelength of maximum intensity is inversely proportional to (thermodynamic) temperature	**B1**
10(b)(i)	λ_{MAX} = 0.50 μm for A **and** 0.65 μm for B	**C1**
	T = 5800 × (0.50 / 0.65) = 4500 K	**A1**
10(b)(ii)	(star B has) greater peak / average wavelength	**B1**
	(star B looks) redder	**B1**
10(c)(i)	apparent wavelength is greater **or** wavelength is greater than known value	**B1**
	(due to) movement of star away (from observer)	**B1**
10(c)(ii)	by examining the (lines in the) spectrum (of light from the star)	**B1**
	and comparing with known spectrum	**B1**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **May/June 2023**

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 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

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	<u>'List rule' guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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.

Question	Answer	Marks
1(a)(i)	force per unit mass	**B1**
1(a)(ii)	force per unit positive charge	**B1**
1(a)(iii)	similarity: • inversely proportional to distance (from point) • points of equal potential lie on concentric spheres • zero at infinite distance *Any point, 1 mark*	**B1**
	difference: • gravitational potential is (always) negative • electric potential can be positive or negative *Any point, 1 mark*	**B1**
1(b)(i)	$g = GM / r^2$	**M1**
	$E = Q / 4\pi\varepsilon_0 r^2$	**M1**
	algebra showing the elimination of r leading to $M / Q = (1 / 4\pi G\varepsilon_0)\,(g / E)$	**A1**
1(b)(ii)	$\alpha = 1 / (4\pi \times 6.67 \times 10^{-11} \times 8.85 \times 10^{-12}) = 1.35 \times 10^{20}$ (kg^2 C^{-2}) **or** $\alpha = (8.99 \times 10^{9}) / (6.67 \times 10^{-11}) = 1.35 \times 10^{20}$ (kg^2 C^{-2})	**A1**
1(c)(i)	$E = \alpha g Q / M$ $= (1.35 \times 10^{20} \times 9.81 \times 4.80 \times 10^{5}) / (5.98 \times 10^{24})$	**C1**
	$= 106$ N C^{-1} **or** 106 V m^{-1}	**A1**
1(c)(ii)	same (direction)	**B1**

Question	Answer	Marks
2(a)	horizontal force on sphere causes centripetal acceleration	**B1**
	weight of sphere is (now) equal to vertical component of tension **or** horizontal and vertical components (of force) (now) combine to give greater tension (in spring)	**B1**
	greater tension in spring so greater extension of spring	**B1**
2(b)(i)	$r = 10.8 \times \sin 27° = 4.9$ cm	**A1**
2(b)(ii)	$T \cos \theta = mg$ **or** $T \cos \theta = W$ **and** $W = mg$	**C1**
	$T \cos 27° = 0.29 \times 9.81$ leading to $T = 3.2$ N	**A1**
2(b)(iii)	$\Delta T = 3.2 - (0.29 \times 9.81)$	**C1**
	$k = \Delta T / \Delta x$ $= [3.2 - (0.29 \times 9.81)] / [10.8 - 8.5]$ $= 0.15$ N cm^{-1}	**A1**
2(c)(i)	centripetal acceleration $= (T \sin \theta) / m$ $= (3.2 \times \sin 27°) / 0.29$	**C1**
	$= 5.0$ m s^{-2}	**A1**

Question	Answer	Marks
2(c)(ii)	$a = r\omega^2$ **and** $\omega = 2\pi / T$ **or** $a = v^2 / r$ **and** $v = 2\pi r / T$	**C1**
	$T = 2\pi \times \sqrt{(0.049 / 5.0)}$ $= 0.62$ s	**A1**

Question	Answer	Marks
3(a)	no <u>net</u> thermal energy is transferred (between them)	**B1**
3(b)(i)	variation (of density with temperature) is linear **or** each temperature has a unique value of density	**B1**
3(b)(ii)	• variation (of density with temperature) is not linear • region where the density does not vary with temperature • different temperatures have the same density *Any two points, 1 mark each*	**B2**
3(c)(i)	boiling point = 80 °C	**A1**
3(c)(ii)	$Q = Pt$ **and** $t = 21$ s (thermal energy supplied = 810 × 21 = 17000 J)	**C1**
	$c = Q / m\Delta\theta$	**C1**
	thermal energy absorbed by beaker = 42 × 0.84 × (80 – 25) (= 1940 J)	**C1**
	s.h.c. of liquid = [(810 × 21) – (42 × 0.84 × (80 – 25))] / [120 × (80 – 25)] = 2.3 J g^{-1} K^{-1}	**A1**
3(d)	sketch: straight diagonal line from 25 °C to 100 °C **and** then horizontal at 100 °C	**B1**
	straight diagonal line starting at 25 °C with gradient approximately half that of the original line	**B1**

Question	Answer	Marks
4(a)	• particles are in (continuous) random motion • particles have negligible volume (compared with the gas) • negligible forces between particles (except during collisions) • (all) collisions (perfectly) elastic • time of collision negligible (in comparison with time between collisions) *Any two points, 1 mark each*	**B2**
4(b)(i)	(general starting equation) $pV = nRT$	**C1**
	$T = (2pV / nR)$ where R is the (molar) gas constant	**A1**
4(b)(ii)	sketch: straight vertical line XY from (V, 2p) to (V, p)	**B1**
	straight horizontal line YZ from (V, p) to (2V, p)	**B1**
	curve with gradient increasing from Z to X from (2V, p) to (V, 2p)	**B1**
4(b)(iii)	XY work done on gas correct (= 0)	**B1**
	ZX increase in internal energy correct (= 0)	**B1**
	YZ work done on gas correct (= $-pV$)	**B1**
	XY increase in internal energy such that the increase in internal energy column adds up to zero	**B1**
	all three thermal energies transferred such that $\Delta U = q + w$ in each row (completely correct answer: <table><tr><th>change</th><th>ΔU</th><th>Q</th><th>w</th></tr><tr><td>X to Y Y to Z Z to X</td><td>$-U$ [$+U$] 0</td><td>$-U$ $U + pV$ $-W$</td><td>0 $-pV$ [$+W$]</td></tr></table>)	**B1**

Question	Answer	Marks
5(a)(i)	correct circuit symbol for a diode shown correctly connected in series with the wires leading into and out of the dotted box	**B1**
5(a)(ii)	smoothing / V_{OUT} is smoothed	**B1**
5(b)(i)	frequency = 1 / 0.04 = 25 Hz	**A1**
5(b)(ii)	$V = V_0 \exp(-t/RC)$ **and** $\tau = RC$ **or** $V = V_0 \exp(-t/\tau)$	**C1**
	3.25 = 5.50 exp (– 0.020 / τ) leading to τ = 0.038 s	**A1**
5(b)(iii)	$\tau = RC$	**C1**
	capacitance = 0.038 / 14000 = 2.7×10^{-6} F	**A1**
5(c)	V_{IN} has constant magnitude in both positive and negative directions	**B1**
	(so) V_{OUT} is (now) constant / V_{OUT} does not vary with time	**B1**

Question	Answer	Marks
6(a)	a region where a force acts on	**M1**
	a current-carrying conductor **or** a <u>moving</u> charge **or** a magnetic material / magnetic pole	**A1**
6(b)	concentric circles around the wire	**B1**
	spacing between circles increases with distance from wire	**B1**
	arrows showing direction of field is clockwise	**B1**
6(c)(i)	$F = BIL$	**C1**
	force per unit length $= BI$ $= 2.6 \times 10^{-3} \times 5.0$ $= 0.013\ \text{N m}^{-1}$	**A1**
6(c)(ii)	to the right	**B1**
6(c)(iii)	force (per unit length) has the same magnitude due to Newton's 3rd law	**B1**
	$0.013 = 1.5 \times 10^{-3} \times I$ current = 8.7 A	**A1**

Question	Answer	Marks
7(a)	wavelength associated with a <u>moving</u> particle	**B1**
7(b)(i)	(electron) diffraction	**B1**
7(b)(ii)	beam spreads out indicating diffraction **or** light and dark regions indicate an interference pattern	**B1**
	electron beam is behaving as a wave	**B1**
7(c)(i)	central blob and concentric rings	**B1**
	rings closer together (than previously)	**B1**
7(c)(ii)	(greater p.d. so) electrons to have greater momentum	**B1**
	greater momentum so decrease in (de Broglie) wavelength	**B1**
	lower (de Broglie) wavelength (for same grating spacing in crystal) causes: smaller diffraction angle **or** smaller angle of intensity maxima (for each order) **or** decrease in fringe spacing in diffraction pattern	**B1**

Question	Answer	Marks
8(a)(i)	specific acoustic impedance = $1200 \times 1400 = 1.68 \times 10^6\ \text{kg m}^{-2}\ \text{s}^{-1}$	**A1**
8(a)(ii)	density of air shown in table as 1.29	**A1**
	speed of sound in tissue shown in table as 1540	**A1**
8(b)(i)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ $= (1680000 - 440)^2 / (1680000 + 440)^2$	**C1**
	$= 0.999$	**A1**
8(b)(ii)	intensity reflection coefficient $= (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ $= (1680000 - 1680000)^2 / (1680000 + 1680000)^2$ $= 0$	**A1**
8(c)	without gel, (almost) all of the (incident) ultrasound is reflected (from skin)	**B1**
	with gel, (almost) all of the (incident) ultrasound is transmitted (into the body)	**B1**

Question	Answer	Marks
9(a)	time for activity (of sample) to halve	**B1**
9(b)	sketch: line with positive gradient starting at (0,0) and extending to t = 80 min	**B1**
	exponential curve, extending from t = 0 to t = 80 min, with gradient of steadily decreasing magnitude	**B1**
	line passing through (0,0), (20, $0.5N_0$) and (40, $0.75\ N_0$)	**B1**
9(c)(i)	every (undecayed) nucleus has the same probability of decay	**M1**
	fewer (undecayed) nuclei remaining (with time), so fewer will decay (in a given time interval)	**A1**
9(c)(ii)	• sample emits in all directions but detector only captures emissions in one direction • some emissions are absorbed before reaching detector • some emissions are scattered within the sample • simultaneous arrival of multiple particles only registers once • some particles may reach detector but not cause ionisation *Any two points, 1 mark each*	**B2**
	measured count rate is less than the activity	**B1**

Question	Answer	Marks
10(a)	speed is (directly) proportional to distance	**M1**
	speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer	**A1**
10(b)	$F = L / (4\pi d^2)$	**C1**
	$= (3.8 \times 10^{31}) / [4\pi \times (1.8 \times 10^{24})^2]$ $= 9.3 \times 10^{-19}$ W m^{-2}	**A1**
10(c)(i)	galaxy is moving away (from the Earth)	**B1**
	wavelength (of light from the galaxy) increased by the Doppler effect / due to redshift	**B1**
10(c)(ii)	$\Delta\lambda / \lambda = v / c$ $v = [(492 - 486) \times 3.00 \times 10^8] / 486$ ($v = 3.7 \times 10^6$ m s^{-1})	**C1**
	$H_0 = v / d$	**C1**
	$= (3.7 \times 10^6) / (1.8 \times 10^{24})$ $= 2.1 \times 10^{-18}$ s^{-1}	**A1**

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.

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

This document consists of **15** 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.

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	<u>'List rule' guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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. Within 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 =) $NkT = \frac{1}{3}Nm<c^2>$ **or** $pV = NkT$ **and** $pV = \frac{1}{3}Nm<c^2>$	**M1**
	leading to $\frac{1}{2}m<c^2> = (3/2)kT$ and $\frac{1}{2}m<c^2> = E_K$	**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
	$\omega = 2\pi / 4.0$ $= 1.6$ rad s^{-1}	A1
4(a)(iii)	$v_0 = \omega x_0$	C1
	$= 1.57 \times 5.0$ $= 7.9$ 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 and maximum L shown as 25 cm	B1
	minimum v shown as –7.9 cm s^{-1} and maximum v shown as +7.9 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 $\pm$ 34 V (*1 mark out of 2 awarded if peak E shown as* $\pm$ 17 V *or* $\pm$ 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 $\times$ 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**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **October/November 2020**

MARK SCHEME

Maximum Mark: 100

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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).
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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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

Abbreviations

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Mark categories

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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. Within 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.
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SEEN	Indicates that a page has been seen.

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

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

Question	Answer	Marks
2(a)	$+q$: thermal energy transfer to system	**B1**
	$+w$: work done on system	**B1**
2(b)(i)	$(W =)\ 2.6 \times 10^5 \times (3.8 - 2.3) \times 10^{-3} = 390$ 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 complete correct answer:	**B1**

change	q / J	w / J	ΔU / J
A to B	(+)1370	–390	(+)980
B to C	0	(+)550	(+)550
C to A	–1530	0	–1530

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)	$v = \omega(x_0^2 - x^2)^{½}$ **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**
	$f = 0.45$ Hz	**A1**
3(c)	$1 / 0.45 = 2\pi \times (L / 9.81)^{½}$	**C1**
	$L = 1.2$ 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**

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 dB	**A1**

Question	Answer	Marks
5(a)	work done per unit charge	B1
	(work done on charge) moving positive charge from infinity	B1
5(b)(i)	$(2.0 \times 10^{-9}) / 4\pi\varepsilon_0(4.0 \times 10^{-2}) + Q / 4\pi\varepsilon_0(8.0 \times 10^{-2}) = 0$	C1
	$Q = 4.0 \times 10^{-9}$ 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
	$v = 3.4 \times 10^5$ 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: • smoothing • timing/(time) delay • tuning • oscillator • blocking d.c. • surge protection • temporary power supply	**B3**
6(b)	(capacitors in series have combined capacitance =) 8 μF	**C1**
	capacitance = 8 + 24 = 32 μF	**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 Ω	**A1**
7(b)(ii)	non-zero value less than 1000 Ω	**A1**

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**
	$= 1.4 \times 10^{-12}$ 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**

Question	Answer	Marks
9(a)	flux density × area	**M1**
	where flux is normal to area	**A1**
	or	
	flux density × area × sin θ	**(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**

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**

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**
	$p = (6.63 \times 10^{-34}) / (544 \times 10^{-9})$ $= 1.22 \times 10^{-27}$ N s	**A1**
11(b)(ii)	energy $= hc / \lambda$	**C1**
	$= 6.63 \times 10^{-34} \times 3.00 \times 10^{8} \times (540^{-1} - 544^{-1}) \times 10^{9}$ $= 2.7 \times 10^{-21}$ J	**A1**
11(c)	(smaller wavelength corresponds to) greater photon energy	**B1**
	any one point from: • (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**

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**
	$560 = 9.9 \times 10^{-7} \times N$ $N = 5.7 \times 10^{8}$	**A1**
12(c)	$A = A_0\, e^{-\lambda t}$ $170 = 560 \exp(-9.9 \times 10^{-7} \times t)$	**C1**
	$t = 1.2 \times 10^{6}$ s	**C1**
	= 14 days	**A1**

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **May/June 2018**

MARK SCHEME

Maximum Mark: 100

Published

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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.
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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.

Question	Answer	Marks
1(a)	force proportional to product of masses and inversely proportional to square of separation	**B1**
	idea of force between point masses	**B1**
1(b)(i)	velocity changes/direction of motion changes/there is an acceleration/there is a resultant force so not in equilibrium	**B1**
1(b)(ii)1.	gravitational force equals/is centripetal force	**C1**
	$GMm/R^2 = mR\omega^2$ **and** $\omega = 2\pi/T$ **or** $Gm/R^2 = mv^2/R$ **and** $v = 2\pi r/T$ **or** $GMm/R^2 = mR\,(2\pi/T)^2$	**M1**
	convincing algebra leading to $k = GM/4\pi^2$	**A1**
1(b)(ii)2.	correct use of R^3/T^2 for one planet (c gives 3.54×10^{21}; e and g both give 3.56×10^{21})	**C1**
	$3.5(5) \times 10^{21} = (6.67 \times 10^{-11} \times M) / 4\pi^2$ $M = 2.1 \times 10^{33}$ kg	**A1**
	two or three values of R^3/T^2 correctly calculated and used in a valid way to find a value for M based on more than one k	**B1**

Question	Answer	Marks
2(a)(i)	straight line through origin indicates acceleration $\propto$ displacement	**B1**
	negative gradient shows acceleration and displacement are in opposite directions	**B1**
2(a)(ii)	$a = -\omega^2 y$ **and** $\omega = 2\pi f$ $4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ *(or other valid read-off)*	**C1**
	$f = 3.8\,\text{Hz}$	**A1**
2(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	**B1**
2(b)(ii)	(just leaves plate when) acceleration = $9.81\,\text{m}\,\text{s}^{-2}$	**C1**
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ **or** $9.81 = 563 \times y_0$	**C1**
	amplitude = 17 mm	**A1**

Question	Answer	Marks
3(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	**B1**
	(energy of) molecules/atoms/particles in random motion	**B1**
3(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	**B1**
	internal energy is (solely) kinetic energy (of particles)	**B1**
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	**B1**
3(b)	$pV = NkT$	**C1**
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 298$	**C1**
	or	
	$pV = nRT$ **and** $N = n \times N_A$	**(C1)**
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 298$ $n = 46.5$ (mol) $N = 46.5 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.8 \times 10^{25}$	**A1**

Question	Answer	Marks
4(a)	e.g. microphone weighing scales/pressure sensor lighters/spark generation watches/clocks/regulation of time	**B1**
4(b)	<u>pulses</u> (of ultrasound)	**B1**
	reflected at boundaries (between media)	**B1**
	(reflected pulses) detected by (ultrasound) generator	**B1**
	Any three from: • time delay (between transmission and receipt) gives information about depth (of boundary) • intensity of reflected pulse gives information about (nature of) <u>boundary</u> • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	**B3**

Question	Answer	Marks
5(a)(i)	west to east	**B1**
5(a)(ii)	above the Equator	**B1**
5(a)(iii)	value in range $(1–300) \times 10^9$ Hz	**A1**
5(b)(i)	gain / dB = $10 \lg (P_2 / P_1)$	**C1**
	$–195 = 10 \lg (P / 3000)$ **or** $195 = 10 \lg (3000 / P)$	**C1**
	power = $9.5 \times 10^{–17}$ W	**A1**
5(b)(ii)	up-link has been (greatly) attenuated (before reaching satellite) **or** down-link signal must be (greatly) amplified (before transmission back to Earth) **or** up-link has (much) smaller intensity/power than down-link	**B1**
	(different frequency) prevents down-link (signal) swamping up-link (signal)	**B1**

Question	Answer	Marks
6(a)	force per unit charge	**B1**
6(b)	$E = Q / (4\pi\varepsilon_0 r^2)$	**C1**
	$2.0 \times 10^4 = Q / (4\pi \times 8.85 \times 10^{–12} \times 0.26^2)$ charge = $1.5 \times 10^{–7}$ C	**A1**
6(c)	charge (= $Q\,[52 / 26]^2$) = $4Q$	**C1**
	additional charge = 3Q	**A1**

Question	Answer	Marks
7(a)	(capacitance =) charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
7(b)(i)	4.5×10^{-6} C	A1
7(b)(ii)	9.0×10^{-8} C	A1
7(b)(iii)	capacitance = (9.0×10^{-8}) / 120	C1
	= 7.5×10^{-10} F	A1
7(c)	total capacitance is halved	B1
	current is halved	B1

Question	Answer	Marks
8(a)(i)	(fraction of) output is combined with the input	**M1**
	output (fraction) subtracted/deducted from input	**A1**
8(a)(ii)	any two valid points e.g.: • greater bandwidth/gain constant over a larger range of frequencies/greater bandwidth • smaller gain	**B2**
8(b)(i)	gain = (–)9600 / 800	**C1**
	= –12	**A1**
8(b)(ii)	**1.** 1.2 V	**B1**
	2. –6 V	**B1**
8(b)(iii)	replace the 9600 Ω resistor with an LDR	**B1**

Question	Answer	Marks
9(a)	using Fleming's left-hand rule force on wire is upwards	**B1**
	by Newton's third law, force on magnet is downwards	**B1**
9(b)(i)	$F = BIL$	**C1**
	$= 3.7 \times 10^{-3} \times 5.1 \times 8.5 \times 10^{-2}$ $= 1.6 \times 10^{-3}$ N	**A1**
9(b)(ii)	$F = 1.6 \times 10^{-3}$ N	**A1**
9(c)	sketch: sinusoidal wave with two cycles	**B1**
	amplitude 2.3×10^{-3} N	**B1**
	period 0.05 s	**B1**

Question	Answer	Marks
10(a)	induced <u>e.m.f.</u> proportional to rate	**M1**
	of <u>change</u> of (magnetic) <u>flux</u> (linkage) **or** of <u>cutting</u> (magnetic) <u>flux</u>	**A1**
10(b)	current in coil produces flux	**B1**
	(by Faraday's law) changing flux induces e.m.f. in ring	**B1**
	current in ring causes field (around ring)	**B1**
	(by Lenz's law) field around ring opposes field around coil	**B1**

Question	Answer	Marks
11(a)(i)	packet/quantum/discrete amount of energy	**M1**
	of electromagnetic radiation	**A1**
11(a)(ii)	(maximum) energy of emitted electrons is independent of intensity **or** no emission of electrons below the threshold frequency regardless of intensity **or** no emission of electrons when photon energy is less than work function (energy) regardless of intensity	**B1**
11(b)	in darkness: conduction band empty so high resistance	**B1**
	in daylight: electrons in valence band absorb photons	**B1**
	in daylight: electrons 'jump' to conduction band	**B1**
	this leaves holes in valence band	**B1**
	more charge carriers in daylight so resistance decreases	**B1**

Question	Answer	Marks
12(a)(i)	$I = I_0 e^{-\mu x}$	**C1**
	$= I_0 \exp(-0.90 \times 2.8)$ $= 0.080\, I_0$	**A1**
12(a)(ii)	$I = I_0 \exp[(-0.90 \times 1.5) \times (-3.0 \times 1.3)]$	**C1**
	$= I_0\ (0.259 \times 0.20)$ $= 0.0052\, I_0$	**A1**
12(b)(i)	difference in degrees of blackening	**M1**
	between structures	**A1**
12(b)(ii)	large difference in intensities so good contrast	**B1**

Question	Answer	Marks
13(a)	emission of particles/radiation by unstable nucleus	**B1**
	spontaneous emission	**B1**
13(b)(i)	use of graph to determine half-life = 14 minutes	**B1**
	hence $\lambda = \ln 2 / (14 \times 60)$ (s^{-1})	**C1**
	N at 14 minutes = 4.4×10^7 **and** $A = \lambda N$	**C1**
	activity $= 4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ $= 3.6 \times 10^4$ Bq	**A1**
	or	
	correct tangent drawn at time t = 14 minutes	**(B1)**
	magnitude of gradient of tangent identified as activity	**(C1)**
	correct working for gradient leading to activity	**(C1)**
	activity = 3.6×10^4 Bq	**(A1)**
13(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ **or** $\lambda = \ln 2 / (14.0 \times 60)$	**C1**
	$\lambda = 8.2 \times 10^{-4}\ s^{-1}$	**A1**

Cambridge International AS & A Level

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PHYSICS **9702/41**

Paper 4 A Level Structured Questions **May/June 2019**

MARK SCHEME

Maximum Mark: 100

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Question	Answer	Marks
1(a)	(F =) GMm / x^2, where G is the (universal) gravitational constant	**B1**
1(b)(i)	$GMm / x^2 = mv^2 / x$ **or** $v^2 = GM / x$	**C1**
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$ so $v = 3.7 \times 10^3$ m s^{-1}	**A1**
1(b)(ii)	potential energy = (–)GMm / x	**C1**
	$E_A = (–)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (3.64 \times 10^6)$ **or** $E_B = (–)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (5.00 \times 10^7)$	**M1**
	correct substitution and subtraction $E_B – E_A$ shown, leading to $\Delta E_p = 8.3 \times 10^9$ J	**A1**
	or	
	ϕ = (–)GM / x **and** potential energy = $m\phi$	**(C1)**
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1 / (3.64 \times 10^6)) – (1 / (5.00 \times 10^7))]$ (= 1.27×10^7 J kg^{-1})	**(M1)**
	$\Delta E_p = 1.27 \times 10^7 \times 650$ $= 8.3 \times 10^9$ J	**(A1)**
1(c)	kinetic energy <u>or</u> potential energy decreases	**B1**
	kinetic energy <u>and</u> potential energy decrease so total energy decreases	**B1**

Question	Answer	Marks
2(a)(i)	$pV = nRT$	**C1**
	$n = (3.0 \times 10^5 \times 210 \times 10^{-6}) / (8.31 \times 270)$	**C1**
	$= 0.028$ mol	**A1**
2(a)(ii)	$V \propto T$ **or** $T = pV / nR$ with value of n from **(i)**	**C1**
	$T = (140 / 210) \times 270$ **or** $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$ $= 180$ K	**A1**
2(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	**C1**
	$= 21$ J	**A1**

Question	Answer	Marks
2(b)	$\Delta U = w + q$	C1
	$= 21 - 53$	C1
	or	
	$\Delta U = (nN_A) \times (3/2)k\Delta T$	(C1)
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	(C1)
	or	
	$\Delta U = (3/2)nR\Delta T$	(C1)
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	(C1)
	$\Delta U = (-)32$ J	A1

Question	Answer	Marks
3(a)(i)	amplitude = 0.020 m	**A1**
3(a)(ii)	T = 0.60 s	**C1**
	f = 1 / T = 1.7 Hz	**A1**
3(a)(iii)	$a = (-)\omega^2 x$ **and** [$\omega = 2\pi f$ **or** $\omega = 2\pi / T$]	**C1**
	$a = (4\pi^2 / 0.60^2) \times 2.0 \times 10^{-2}$ $= 2.2$ m s^{-2}	**A1**
3(b)	$1.67 = (1 / 2\pi) \times [(24 \times 10^{-4} \times \rho \times 9.81) / 0.23]^{1/2}$	**C1**
	$\rho = 1.1 \times 10^3$ kg m^{-3}	**A1**
3(c)	wave starting with a peak at (0,6)	**B1**
	wave with same period (or slightly greater)	**B1**
	peak height decreasing successively	**B1**

Question	Answer	Marks
4(a)(i)	loss of (signal) power/amplitude/intensity	**B1**
4(a)(ii)	unwanted/random signal	**B1**
	superposed on (transmitted) signal	**B1**
4(b)	noise can be eliminated (from digital signals) **or** signal can be regenerated (from digital signals)	**B1**
4(c)(i)	010<u>1</u>	**A1**
4(c)(ii)	1000 at t = 4.0 ms	**B1**
	0110 at t = 5.0 ms **and** 0100 at t = 6.0 ms	**B1**
4(d)	series of equally-spaced steps of width 1 ms	**B1**
	each step in correct time interval (0–1 ms, 1–2 ms, 2–3 ms, 3–4 ms)	**B1**
	correct step heights (2, 6, 4 and 5)	**B1**

Question	Answer	Marks
5(a)	force per unit charge	**B1**
	(force on) positive charge	**B1**
5(b)(i)	field changes <u>direction</u> (between A and B)/field is zero at a point (between A and B)	**M1**
	so charges have same sign	**A1**
5(b)(ii)	Any one from: • field is (also) influenced by charge B • charge A is not isolated/is not the only charge present • field is due to two/both charges • field is the resultant of two fields	**B1**
5(b)(iii)	$E = Q / (4\pi\varepsilon_0 x^2)$	**C1**
	at x = 10 cm, $E_A = E_B$	**C1**
	$Q_A / 10^2 = Q_B / 5^2$ $Q_A / Q_B = 4.0$	**A1**

Question	Answer	Marks
6(a)	Any valid two points e.g.: • to store (electrical) energy • smoothing/reduce ripple (on direct voltages/currents) • to block d.c. • timing/time delay (circuits) • in oscillator (circuits) • in tuning (circuits) • to prevent arcing/sparks	**B2**
6(b)	clear indication of equal charge on each capacitor	**B1**
	$E = V_1 + V_2 + V_3$ **and** $V = Q / C$	**M1**
	completion of algebra leading to $1 / C = 1 / C_1 + 1 / C_2 + 1 / C_3$	**A1**
6(c)(i)	three capacitors connected in parallel	**B1**
6(c)(ii)	parallel combination of three capacitors connected in series with one capacitor	**B1**

Question	Answer	Marks
7(a)(i)	(amplifier) gain is very large/infinite	**B1**
	for amplifier not to saturate, $V^+ = V^-$ **or** feedback (loop) ensures $V^+ = V^-$	**B1**
	V^+ is at earth/0 V so V^- is (almost) at earth/0 V	**B1**
7(a)(ii)	gain = (–)5200 / 800 **or** (–)5.2 / 0.80	**C1**
	= –6.5	**A1**

Question	Answer	Marks
7(b)	(at saturation,) $V_{OUT} = 5\,V$	C1
	p.d. across R = 5 – 2.3 = 2.7 (V)	C1
	resistance = 2.7 / (30 × 10^{-3}) = 90 Ω	A1
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω R_{total} = 5.0 / 0.030 = 167 Ω	(C1)
	$R_{resistor}$ (= 167 – 77) = 90 Ω	(A1)
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω 77 / ($R_{resistor}$ + 77) × 5 = 2.3	(C1)
	$R_{resistor}$ = 90 Ω	(A1)
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω $R_{resistor}$ = 77 × (2.7 / 2.3)	(C1)
	$R_{resistor}$ = 90 Ω	(A1)

Question	Answer	Marks
8(a)(i)	region where a force is exerted on: a magnetic pole **or** a moving charge **or** a current-carrying wire	**B1**
8(a)(ii)	arrow on axis of solenoid pointing downwards labelled P	**B1**
8(b)(i)	<u>direction</u> of induced e.m.f./current	**M1**
	(tends to) oppose the change causing it	**A1**
8(b)(ii)	magnetic field in solenoid is increasing	**B1**
	field in coil in opposite direction to oppose increase	**B1**
	arrow inside or just above small coil pointing in opposite direction to P	**B1**
8(c)	e.m.f. $= N\Delta\phi / \Delta t$	**C1**
	$= (75 \times 1.4 \times 10^{-3} \times 2 \times 7.0 \times 10^{-4}) / 0.12$	**C1**
	$= 1.2 \times 10^{-3}$ V	**A1**

Question	Answer	Marks
9(a)	nuclei precess	**B1**
	precession is about direction of magnetic field	**B1**
	frequency of precession depends on field strength **or** frequency of precession is in radio-frequency range	**B1**
9(b)	Any two points from: • frequency (of precession) depends on position • to locate position of (spinning) nuclei • to change region where nuclei are detected	**B2**

Question	Answer	Marks
10(a)	$V_{MAX} = 15\,V$	**A1**
10(b)	$210 = 2\pi / T$	**C1**
	$T = 0.0299\,s$	**C1**
	$(t_2 - t_1) = 0.060\,s$	**A1**

Question	Answer	Marks
11(a)	Any three points from: • (max) energy of emitted electrons depends on frequency • (max) energy of emitted electrons does not depend on intensity • rate of emission of electrons depends on intensity (at constant frequency) • existence of frequency below which no emission of electrons • instantaneous emission of electrons • increasing the frequency at constant intensity decreases the rate of emission of electrons	**B3**
11(b)(i)	photon energy $= hc / \lambda$	**C1**
	$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (380 \times 10^{-9})$ $(= 5.23 \times 10^{-19}\ \text{J})$	**C1**
	$= 3.3\ \text{eV}$	**A1**
11(b)(ii)	photon energy must be greater than work function (energy)	**B1**
	so sodium and calcium	**B1**
11(c)	$\lambda = h / p$	**C1**
	$p = (6.63 \times 10^{-34}) / (380 \times 10^{-9})$ $= 1.74 \times 10^{-27}\ \text{N s}$	**C1**
	force $= 1.74 \times 10^{-27} \times 7.6 \times 10^{14}$ $= 1.3 \times 10^{-12}\ \text{N}$	**A1**

Question	Answer	Marks
12(a)(i)	$\Delta N / \Delta T$	**B1**
12(a)(ii)	$\Delta N / N$	**B1**
12(a)(iii)	$\Delta N / (N \Delta T)$	**B1**
12(b)(i)	**1.** mass change = 5.60×10^{-3} u	**A1**
	2. energy = $(\Delta)mc^2$	**C1**
	= $5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ (= 8.36×10^{-13} J)	**C1**
	= 0.84 pJ	**A1**
12(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	**B1**
	energy of γ-ray photon	**B1**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **October/November 2020**

MARK SCHEME

Maximum Mark: 100

Published

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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.

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. Within 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)	work done per unit mass	**B1**
	(work done) moving mass from infinity (to the point)	**B1**
1(b)(i)	gravitational potential energy = (–)GMm / r	**C1**
	$\Delta E_P = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 2.4 \times 10^3 \times [(6.4 \times 10^6)^{-1} - (1.2 \times 10^7)^{-1}]$	**C1**
	or	
	$\Delta \phi = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times [(6.4 \times 10^6)^{-1} - (1.2 \times 10^7)^{-1}]$	**(C1)**
	$\Delta E_P = m\Delta\phi$	**(C1)**
	$\Delta E_P = 7.0 \times 10^{10}$ J	**A1**
1(b)(ii)	$GMm / r^2 = mv^2 / r$	**C1**
	$v^2 = GM / r$ $= (6.67 \times 10^{-11} \times 6.0 \times 10^{24}) / (1.2 \times 10^7)$	**C1**
	$v = 5800$ m s^{-1}	**A1**
1(c)	any one point from: • smaller gain in energy required if orbit is west to east • smaller change in velocity if orbit is west to east • smaller gain in energy if orbit is in same direction as Earth's rotation • smaller change in velocity if orbit is in same direction as Earth's rotation • satellite already moving west to east at launch • Earth's rotation is from west to east	**B1**

Question	Answer	Marks
2(a)	sum of potential energy and kinetic energy (of particles)	**B1**
	(total) energy of random motion of particles	**B1**
2(b)(i)	$pV = nRT$	**C1**
	$2.60 \times 10^5 \times 2.30 \times 10^{-3} = n \times 8.31 \times 180$ $n = 0.400$ mol	**A1**
2(b)(ii)	$(2.30 \times 10^{-3}) / 180 = (3.80 \times 10^{-3}) / T$ **or** $2.60 \times 10^5 \times 3.80 \times 10^{-3} = 0.400 \times 8.31 \times T$	**C1**
	$T = 297$ K	**A1**
2(c)(i)	$\Delta W = p\Delta V$ $= 2.60 \times 10^5 \times (2.30 - 3.80) \times 10^{-3}$	**C1**
	$= (-)390$ J	**A1**
	negative because work is done by gas **or** negative because work is done against atmospheric pressure **or** negative because volume of gas increases	**B1**
2(c)(ii)	$\Delta U = (980 - 390)$ $= 590$ J	**A1**

Question	Answer	Marks
3(a)	acceleration (directly) proportional to displacement	**B1**
	acceleration is in opposite <u>direction</u> to displacement **or** acceleration is (directed) towards a fixed point	**B1**
3(b)(i)	zero	**B1**
3(b)(ii)	E_T is maximum potential energy = mgh $E_T = 94 \times 10^{-3} \times 9.81 \times 0.90 \times 10^{-2}$	**C1**
	$= 8.3 \times 10^{-3}$ J	**A1**
3(b)(iii)	$E_{MAX} = ½\, mv_0^2$ **and** $v_0 = \omega x_0$ **or** $E_{MAX} = ½m(\omega x_0)^2$	**C1**
	$8.3 \times 10^{-3} = ½ \times 94 \times 10^{-3} \times \omega^2 \times (12.7 \times 10^{-2})^2$ …leading to $\omega = 3.3$ rad s^{-1}	**A1**
3(c)	$T = 2\pi / \omega$	**C1**
	$2\pi / 3.3 = 2\pi \times (L / 9.81)^{½}$	**C1**
	$L = 0.90$ m	**A1**

Question	Answer	Marks
4(a)	any two points from: • signal can be regenerated/noise can be removed • signal can be encrypted • signal can be checked for errors • multiplexing is possible • <u>circuits</u> are more reliable/cheaper • <u>data</u> can be transmitted at a greater <u>rate</u>	**B2**
4(b)(i)	right-hand zero underlined (011<u>0</u>)	**B1**
4(b)(ii)	analogue signals given as: 3.0, 4.8, 1.0	**B1**
	0011 at 0.30 ms **and** 0001 at 0.50 ms	**B1**
	0100 at 0.40 ms	**B1**
4(c)	series of steps, all of width 0.1 ms	**B1**
	steps levels, in order, at output voltage 0, 5, 6, 3 and 4 mV 2 marks: all levels correct 1 mark: one level incorrect and all others correct **or** one level omitted and last step shown at 1 mV	**B2**

Question	Answer	Marks
5(a)(i)	region (of space)	**B1**
	where a particle experiences a force	**B1**
5(a)(ii)	similarity – any one point from: • both have an inverse square variation • both decrease with distance • both are radial	**B1**
	difference – any one point from: • gravitational field always towards (the mass) • electric field can be towards or away from (the charge)	**B1**
5(b)(i)	$E = Q / 4\pi\varepsilon_0 x^2$	**C1**
	$Q = 4\pi \times 8.85 \times 10^{-12} \times 84 \times 0.15^2$ $= 2.1 \times 10^{-10}$ C	**A1**
5(b)(ii)	$E = 84 \times (0.15 / 0.45)^2$ **or** $E = (2.1 \times 10^{-10}) / (4\pi \times 8.85 \times 10^{-12} \times 0.45^2)$	**C1**
	$E = 9.3$ V m^{-1}	**A1**
5(c)	line at $E = 0$ from $x = 0$ to $x = 0.15$ m	**B1**
	smooth curve with decreasing negative gradient throughout, from $x = 0.15$ m to $x = 0.45$ m, passing through (0.15, 84)	**B1**
	line passing through (0.45, 9.3)	**B1**

Question	Answer	Marks
6(a)(i)	charge per unit potential (difference)	M1
	charge on one plate and potential difference between the plates	A1
6(a)(ii)	any three points from: • smoothing • timing/(time) delaying • tuning • oscillator • blocking d.c. • surge protection • temporary power supply	B3
6(b)(i)	parallel combination of two in series and a single capacitor	B1
6(b)(ii)	one capacitor in series with two in parallel	B1

Question	Answer	Marks
7(a)	X-ray photon produced when electron is decelerated	B1
	larger acceleration results in larger photon energy	B1
	continuous range of accelerations so continuous spectrum of wavelengths/frequencies	B1
7(b)	electron in (inner shell of) target atom is excited (on collision)	B1
	electron de-excites causing emission of a photon	B1
	discrete energy levels so discrete photon wavelengths	B1

Question	Answer	Marks
8(a)(i)	gain is the same for all frequencies	**B1**
8(a)(ii)	no (time) delay in change in output when input is changed	**B1**
8(b)(i)	(at saturation,) V_{OUT} = 5.0 V	**C1**
	gain = 5.0 / 0.40 = 12.5 or 13	**A1**
8(b)(ii)	12.5 = 1 + (R / 800)	**C1**
	R = 9200 Ω	**A1**

Question	Answer	Marks
9(a)(i)	(induced) e.m.f. (directly) proportional to rate	**M1**
	of change of magnetic flux (linkage)	**A1**
9(a)(ii)	e.m.f. = 0 apart from thin pulses at t_1 and t_2	**B1**
	rectangular pulses centred on t_1 and t_2, of widths 2 small squares and 1 small square respectively	**B1**
	e.m.fs. at t_1 and t_2 have opposite polarities	**B1**
	magnitude of e.m.f. at t_2 double the magnitude of e.m.f. at t_1	**B1**
9(b)	V_H shown as zero before (t_1 – 2 squares) and after (t_2 + 2 squares) and rises to a constant non-zero value between t_1 and t_2	**M1**
	change at t_1 shown as 2 small squares wide and change at t_2 shown as 1 small square wide	**A1**

Question	Answer	Marks
10(a)	concentric circles centred on the wire	**B1**
	separation of lines increasing with distance from wire	**B1**
	arrows show anti-clockwise direction	**B1**
10(b)(i)	current in (each) wire creates a magnetic field (at the other wire)	**B1**
	current (in wire) at 90° to field causes force	**B1**
10(b)(ii)	force on each wire towards other wire/attractive	**B1**
10(c)	Newton's third law pair of forces so yes (forces are equal) **or** force proportional to product of both currents so yes (forces are equal)	**B1**

Question	Answer	Marks
11(a)	any two points from: • (maximum) kinetic energy of electrons is independent of intensity • maximum kinetic energy of electrons depends on frequency • no time delay (between illumination and emission)	**B2**
11(b)(i)	(for $E_{MAX} = 0$,) $1 / \lambda_0 = 1.93 \times 10^6$ (m^{-1})	**C1**
	$f_0 = 3.00 \times 10^8 \times 1.93 \times 10^6$ $= 5.8 \times 10^{14}$ Hz	**A1**
11(b)(ii)	$hc / \lambda = \Phi + E_{MAX}$	**C1**
	hc = gradient	**C1**
	gradient = e.g. $[(0.40 – 0.20) \times 1.60 \times 10^{–19}] / [(2.25 – 2.09) \times 10^6]$ (*working needed*) $(= 2.0 \times 10^{–25})$	**M1**
	$h = (2.0 \times 10^{–25}) / (3.00 \times 10^8) = 6.7 \times 10^{–34}$ J s (*both working and answer needed*)	**A1**
11(c)	straight line with same gradient as the original	**B1**
	straight line with x-axis intercept greater than 1.93×10^6 m^{-1}	**B1**

Question	Answer	Marks
12(a)(i)	energy required to separate nucleons (of nucleus)	**M1**
	to infinity	**A1**
12(a)(ii)	a (single) large nucleus <u>divides</u> to form (smaller) nuclei	**B1**
	any one point from: • initiated by neutron bombardment • resulting nuclei are of similar size • binding energy per nucleon increases • total binding energy increases • neutrons released • combined mass of smaller nuclei is less than mass of large nucleus	**B1**
12(b)	binding energy per nucleon is a maximum at around $A = 56$	**B1**
	products of splitting a ^{56}Fe nucleus must have a lower total binding energy	**B1**
	(reaction would require) a net input of energy	**B1**

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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	<u>‘List rule’ guidance</u> 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.

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 independent 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 method 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 compensatory 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 answer 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. Within 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)	acceleration perpendicular to velocity	**B1**
1(b)(i)	decreases	**B1**
1(b)(ii)	(acceleration of) 9.8 m s^{-2} is caused by weight of car **or** centripetal force must be greater than weight of car	**B1**
	(acceleration > 9.8 m s^{-2}) requires contact <u>force</u> from track **or** (centripetal force > weight) requires contact <u>force</u> from track	**B1**
1(c)	$\frac{1}{2}mv_Y^2 = \frac{1}{2}mv_X^2 - mgh$	**C1**
	$a = v^2 / r$	**C1**
	$v_Y^2 = 3.8^2 - 2 \times 9.81 \times 0.62$ so $v_Y = 1.5$ m s^{-1} $a = 1.5^2 / 0.31 = 7.3$ m s^{-2} (which is less than 9.8 m s^{-2}) so no	**A1**
	or	
	$v_Y = \sqrt{(9.81 \times 0.31)} = 1.74$ m s^{-1} so $v_X^2 = 1.74^2 + 2 \times 9.81 \times 0.62$ $v_X = 3.9$ m s^{-1} (which is greater than 3.8 m s^{-1}) so no	**(A1)**
1(d)	acceleration is independent of mass so makes no difference **or** mass cancels in the equation so makes no difference	**B1**

Question	Answer	Marks
2(a)	(gravitational) field strength equals (gravitational) potential gradient	**M1**
	reference to minus sign	**A1**
2(b)(i)	potential is zero at infinity	**B1**
	(gravitational) force is attractive	**B1**
	(test) mass getting closer (from infinity) loses potential energy	**B1**
2(b)(ii)	• potential at (surface of) planet is smaller than at (surface of) moon • potential gradient at (surface of) planet is smaller than at (surface of) moon • magnitude of potential varies inversely with distance from centre near the spheres • (point of) maximum potential is nearer to moon than planet *Any two points, 1 mark each*	**B2**
2(b)(iii)	sketch: one curve, starting with gradient of decreasing magnitude at 2R and finishing with gradient of increasing magnitude at $D – R$	**B1**
	field strength shown as zero (only) near the point of maximum potential	**B1**
	negative field strength near one sphere and positive field strength near the other	**B1**

Question	Answer	Marks
3(a)(i)	no loss of <u>kinetic</u> energy	**B1**
3(a)(ii)	• <u>molecules</u> have negligible volume (compared with gas/container) • no forces between <u>molecules</u> (except during collisions) • <u>molecules</u> are in random motion • collisions are instantaneous *Any two points, 1 mark each*	**B2**
3(b)(i)	$2mu$	**A1**
3(b)(ii)	$2L / u$	**A1**
3(b)(iii)	force = change in momentum / time = $2mu / (2L / u)$ $= mu^2 / L$	**A1**
3(b)(iv)	pressure = force / area = $(mu^2 / L) / L^2$ $= mu^2 / L^3$	**A1**
3(c)	$pV = NkT$	**C1**
	$NkT = \frac{1}{3}Nm<c^2>$ leading to $\frac{1}{2}m<c^2> = (3/2)kT$ <u>and</u> $\frac{1}{2}m<c^2> = E_K$	**A1**
3(d)	$\frac{1}{2} \times 3.34 \times 10^{-27} \times <c^2> = (3/2) \times 1.38 \times 10^{-23} \times (25 + 273)$	**C1**
	r.m.s. speed = 1.9×10^3 m s^{-1}	**A1**

Question	Answer	Marks
4(a)	straight line through the origin	**B1**
	negative gradient	**B1**
4(b)	$a = (–)\omega^2 x$ **and** $T = 2\pi / \omega$	**C1**
	e.g. $\omega = \sqrt{(0.80 / 0.12)}$ (*any correct pair of values of a and x*) (= 2.58 rad s^{-1})	**C1**
	$T = 2\pi / 2.58$ = 2.4 s	**A1**
4(c)(i)	Point labelled P at one end of the line	**B1**
4(c)(ii)	Point labelled Q at displacement with magnitude more than half but less than maximum	**B1**

Question	Answer	Marks
5(a)(i)	unmodulated (radio) waves would interfere with each other **or** not modulating would require aerials too long (to be practical)	**B1**
5(a)(ii)	advantage: • can transmit higher frequencies • higher quality <u>reproduction</u> • less prone to interference • same frequency can be used in different areas (*any one point*)	**B1**
	disadvantage: • takes up greater bandwidth • shorter range of transmission • requires a greater number of transmitting aerials (*any one point*)	**B1**
5(b)	AM amplitude: min. 8 mV **and** max. 12 mV	**B1**
	AM frequency: min. 100 kHz **and** max. 100 kHz	**B1**
	FM amplitude: min. 10 mV **and** max. 10 mV	**B1**
	FM frequency: min. 90 kHz **and** max. 110 kHz	**B1**
5(c)	8.4 kHz	**A1**

Question	Answer	Marks
6(a)	work done per unit charge	**B1**
	(work done in) moving positive charge from infinity	**B1**
6(b)	$C = Q / V$	**C1**
	$V = Q / (4\pi\varepsilon_0 r)$ and so $C = Q / [Q / (4\pi\varepsilon_0 r)] = 4\pi\varepsilon_0 r$	**A1**
6(c)	$Q = 4\pi\varepsilon_0 rV \quad = 4\pi \times 8.85 \times 10^{-12} \times 0.13 \times 4500$ $(= 6.5 \times 10^{-8}\ \text{C})$	**C1**
	$(Q - q) / 13 = q / 5.2$	**C1**
	$5.2Q - 5.2q = 13q$, so $q = (5.2 / 18.2)Q$ $q \quad = (5.2 / 18.2) \times 6.5 \times 10^{-8}$ $= 1.9 \times 10^{-8}\ \text{C}$	**A1**
	or	
	$V_T = Q_T / C_T$ $= 6.5 \times 10^{-8} / [4\pi \times 8.85 \times 10^{-12} \times (0.13 + 0.052)]$ $(= 3210\ \text{V})$	**(C1)**
	$q \quad = 4\pi \times 8.85 \times 10^{-12} \times 0.052 \times 3210$ $= 1.9 \times 10^{-8}\ \text{C}$	**(A1)**

Question	Answer	Marks
7(a)	output voltage / input voltage	**M1**
	input (voltage) is difference between (inverting and non-inverting) inputs	**A1**
7(b)	• reduces the gain • greater bandwidth • more stable *Any two points, 1 mark each*	**B2**
7(c)(i)	inverting amplifier	**B1**
7(c)(ii)	X marked anywhere between right-hand edge of 480 Ω resistor, left-hand edge of 1.2 kΩ resistor and the inverting input	**B1**
7(c)(iii)	gain $= (–)R_f / R_i$	**C1**
	$= (–)1200 / 480$ $= –2.5$	**A1**
7(c)(iv)	$V_{IN} = 6.5 / (–2.5)$ $= –2.6$ V	**A1**
7(c)(v)	$(–2.5) \times (–5.4) = +13.5$ V, and so output saturates $V_{OUT} = (+)8.0$ V	**A1**

Question	Answer	Marks
8(a)(i)	arrow from Q pointing downwards, labelled B	**B1**
8(a)(ii)	arrow from Q pointing towards P, labelled F	**B1**
8(b)(i)	force is proportional to product of both currents (I and $2I$) **or** Newton's third law	**B1**
	forces are equal	**B1**
8(b)(ii)	opposite	**B1**

Question	Answer	Marks
9(a)(i)	emission of electrons (from a metal surface)	**B1**
	when electromagnetic radiation is incident (on electrons)	**B1**
9a(ii)	<u>minimum</u> energy required for an electron to leave surface	**B1**
9(b)(i)	threshold (frequency)	**B1**
9(b)(ii)	• photons are (discrete) packets of energy • energy of photons depends on frequency (of EM radiation) • electrons can only absorb a single photon (of energy) *Any two points, 1 mark each*	**B2**
	emission only possible if photon energy is at least the work function	**B1**
9(b)(iii)	work function = hf_0 $= 6.63 \times 10^{-34} \times 6.93 \times 10^{14}$	**C1**
	$= 4.59 \times 10^{-19}$ (J) $= 4.59 \times 10^{-19} / 1.60 \times 10^{-19}$ (eV) $= 2.87$ eV	**A1**

Question	Answer	Marks
10(a)(i)	to increase the magnetic flux linkage (between the coils)	**B1**
10(a)(ii)	to reduce energy losses	**B1**
	by reducing induced currents	**B1**
10(b)(i)	maximum V_{OUT} = 12 000 × (625 / 25 000) = 300 V	**A1**
10(b)(ii)	r.m.s. current = 300 / (640 × √2) = 0.33 A	**A1**
10(b)(iii)	sketch: sinusoidal shape in positive half of the graph, sitting with 'minima' resting on the time-axis (at P = 0)	**B1**
	each 'cycle' shown repeating every 20 ms	**B1**
	maximum P shown as 140 W	**B1**
10(c)	power curve is symmetrical about the midpoint (on the power axis)	**B1**
	mean power is half the peak power	**B1**

Question	Answer	Marks
11(a)	generates <u>ultrasound</u>	**B1**
	detects <u>reflected</u> ultrasound	**B1**
	applied p.d. causes crystal to vibrate **or** vibrations cause crystal to generate an e.m.f.	**B1**
11(b)(i)	product of density and speed	**M1**
	speed of ultrasound in medium	**A1**
11(b)(ii)	difference between (the specific acoustic impedances)	**C1**
	• if similar/same then reflection coefficient is zero/very low • if very different then reflection coefficient is (nearly) 1 • the lower the difference means lower the reflection coefficient (*any one point*)	**A1**

Question	Answer	Marks
12(a)(i)	cannot predict when a particular nucleus will decay **or** cannot predict which nucleus will decay next	**B1**
12(a)(ii)	(decay is) not affected by external (environmental) factors	**B1**
12(b)(i)	$A = A_0 \exp(-\lambda t)$ and so $\ln A = \ln A_0 - \lambda t$ gradient of line = (–)λ	**C1**
	$\lambda = (36.4 - 35.0) / (20 - 0)$ (= 0.07(0) min^{-1})	**C1**
	half-life = ln 2 / λ = ln 2 / 0.070 = 10 min	**A1**
	or	
	$A_0 = \exp(-36.4) = 6.43 \times 10^{15}$ (Bq)	**(C1)**
	$A_0 / 2 = 3.21 \times 10^{15}$ (Bq), so $\ln(A_0 / 2) = 35.7$	**(C1)**
	read off half-life = 10 min	**(A1)**
	or	
	(at one half-life,) $\ln A = 36.4 - \ln 2$	**(C1)**
	$= 35.7$	**(C1)**
	read off half-life = 10 min	**(A1)**

Question	Answer	Marks
12(b)(ii)	$A = \lambda N$	**C1**
	N = mass / (nucleon number $\times$ u) **or** N = (mass / nucleon number) $\times$ N_A	**C1**
	exp(36.4) = (1.17 $\times$ 10^{-3} $\times$ 5.66 $\times$ 10^{-7}) / (nucleon number $\times$ 1.66 $\times$ 10^{-27}) **or** exp(36.4) = (1.17 $\times$ 10^{-3} $\times$ 5.66 $\times$ 10^{-4} $\times$ 6.02 $\times$ 10^{23}) / nucleon number nucleon number = 62	**A1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 2019**

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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Cambridge Assessment International Education

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.

Question	Answer	Marks
1(a)	(F =) GMm / x^2, where G is the (universal) gravitational constant	**B1**
1(b)(i)	angle = $(1.2 \times 10^{-3}) / (8.0 \times 10^{-2}) = 1.5 \times 10^{-2}$ (rad)	**B1**
1(b)(ii)	torque $= 1.5 \times 10^{-2} \times 9.3 \times 10^{-10}$ $= 1.4 \times 10^{-11}$ N m	**A1**
1(c)(i)	force $\times\ 8.0 \times 10^{-2} = 1.4 \times 10^{-11}$	**C1**
	$(G \times 1.3 \times 7.5 \times 10^{-3} \times 8.0 \times 10^{-2}) / (6.0 \times 10^{-2})^2 = 1.4 \times 10^{-11}$	**C1**
	$G = 6.4 \times 10^{-11}$ N m^2 kg^{-2}	**A1**
1(c)(ii)	Any one from: • law applies only to point masses/spheres are not point masses • radii of spheres not small compared with separation • spheres may not be uniform • the masses are not isolated • force between L and rod • spheres may be charged/may be electrostatic force (between spheres)	**B1**

Question	Answer	Marks
2(a)(i)	**1.** energy transfer to the system by heating	**B1**
	2. (external) work done on the system	**B1**
2(a)(ii)	decrease in internal energy	**B1**
2(b)(i)	no change (in internal energy)	**B1**
	(because) no change in temperature	**B1**
2(b)(ii)	work done $= p\Delta V$ $= (–)1.6 \times 10^5 \times (2.4 – 0.87) \times 10^{–3}$	**C1**
	$= (–)240$ J	**A1**
2(b)(iii)	first row all correct (0, 480, 480)	**A1**
	second row all correct (–1100, 0, –1100)	**A1**
	final column of third row calculated correctly from the two values above it, so that the final column adds up to 0	**A1**
	second column in final row correct, with correct negative sign **and** first column in final row calculated correctly so that it adds to the second column to give the third column (fully correct table is: 0 | 480 | 480 –1100 | 0 | –1100 860 | –240 | 620)	**A1**

Question	Answer	Marks
3(a)(i)	0.10 s **or** 0.30 s **or** 0.50 s **or** 0.70 s **or** 0.90 s	**A1**
3(a)(ii)	0 **or** 0.40 s **or** 0.80 s	**A1**
3(b)(i)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / 0.40$ $= 16\ \text{rad s}^{-1}$	**A1**
3(b)(ii)	$v_0 = \omega x_0$	**C1**
	$= 15.7 \times 2.5 \times 10^{-2}$ $= 0.39\ \text{m s}^{-1}$	**A1**
	or	
	tangent drawn at steepest part and working to show attempted calculation of gradient	**(C1)**
	leading to $v_0 = 0.39\ \text{m s}^{-1}$ (*allow* ± *0.15 m s*$^{-1}$)	**(A1)**
3(b)(iii)	$a_0 = \omega^2 x_0$	**C1**
	$a_0 = (15.7^2 \times 2.5 \times 10^{-2})$ $= 6.2\ \text{m s}^{-2}$	**A1**
	or	
	$a_0 = \omega v_0$	**(C1)**
	$a_0 = 15.7 \times 0.39$ $= 6.2\ \text{m s}^{-2}$	**(A1)**

Question	Answer	Marks
3(c)	period is shorter/lower	**B1**
	Any one from: • greater spring constant/stiffness • (restoring) force is greater (for any given extension) • acceleration is greater (for any given extension) • greater energy/maximum speed (for a given amplitude)	**B1**

Question	Answer	Marks
4(a)	product of density and speed	**M1**
	speed of sound in medium	**A1**
4(b)	Any two from: • if $Z_A \gg Z_B$ then ratio is (nearly) zero **or** if $Z_B \gg Z_A$ then ratio is (nearly) zero **or** if Z_B and Z_A are very different then ratio is (nearly) zero **or** the greater the difference the lower the ratio • if $Z_A \approx Z_B$ then ratio is (nearly) 1 **or** if $Z_A = Z_B$ then ratio is 1 **or** the smaller the difference the closer the ratio to 1 (**not** 'large') • $I_T / I_0 = 1 - [(Z_A - Z_B)^2 / (Z_A + Z_B)^2]$	**B2**
4(c)	$I = I_0 e^{-\mu x}$	**C1**
	$0.34 = \exp(-23 \times x)$	**C1**
	$x = 0.047$ m	**A1**

Question	Answer	Marks
5(a)(i)	loss of (signal) power/amplitude/intensity	**B1**
5(a)(ii)	unwanted/random signal	**B1**
	superposed on (transmitted) signal	**B1**
5(b)(i)	attenuation = 10 lg(P_2 / P_1)	**C1**
	attenuation per unit length = (1 / L) × 10 lg(P_2 / P_1) = (1 / 52) × 10 lg [(2.5 × 10^{-3}) / (7.8 × 10^{-16})]	**C1**
	= 2.4 dB km^{-1}	**A1**
5(b)(ii)	gain / dB = 10 lg(P_2 / P_1) 115 = 10 lg [P / (7.8 × 10^{-16})]	**C1**
	P = 2.5 × 10^{-4} W	**A1**

Question	Answer	Marks
6(a)	work done per unit charge	**B1**
	(work done) moving positive charge from infinity	**B1**
6(b)	straight line with non-zero gradient from $x = 0$ to $x = d$	**B1**
	line with gradient of constant sign and end-points between which $\Delta V = V_0$ and $\Delta x = d$	**B1**
	line passes through (d, 0) and (0, $+V_0$) with negative gradient throughout	**B1**
6(c)	V constant (and non-zero) from $0 \rightarrow R$ and from $(D - R) \rightarrow D$	**B1**
	equal (non-zero) values of (magnitude of) V at R and $(D - R)$.	**B1**
	curve (with a minimum) from R to $(D - R)$ with V always positive	**B1**
	minimum at mid-point of curve	**B1**

Question	Answer	Marks
7(a)	Any five from: • (as temperature rises) energy of electrons increases • electrons (have enough energy to) cross forbidden band • electrons enter conduction band • leaving holes in valence band • both holes and electrons act as charge carriers • more charge carriers results in lower resistance • increased lattice vibrations outweighed by increase in (number of) charge carriers	**B5**
7(b)	(at 10 °C resistance is) 2.55 kΩ	**C1**
	new potential difference $= 9.00 \times 2.55 / (2.55 + 12.0)$ $= 1.58$ V	**C1**
	change in p.d. = 0.58 V	**A1**
7(c)	change of resistance with temperature is not linear	**B1**
	change in potential with resistance is not linear **or** potential divider equation is non-linear	**B1**

Question	Answer	Marks
8(a)(i)	$v_N = 3.4 \times 10^7 \times \sin 30°$ $= 1.7 \times 10^7\ \text{m s}^{-1}$	**A1**
8(a)(ii)	$mv^2 / r = Bqv$ **or** $r = mv / Bq$	**C1**
	$r = (9.11 \times 10^{-31} \times 1.7 \times 10^7) / (3.2 \times 10^{-3} \times 1.60 \times 10^{-19})$	**C1**
	$= 0.030\ \text{m}$	**A1**
8(b)	zero	**B1**
8(c)	helix/coil	**B1**

Question	Answer	Marks
9(a)(i)	relay coil shown connected between diode and earth	**B1**
	switch shown connected across lamp	**B1**
9(a)(ii)	Any one from: • (for diode to conduct) current flow is into output of op-amp • when earth is at higher potential diode is forward biased • diode blocks current when output positive • diode must conduct	**M1**
	so V_{OUT} is negative	**A1**
9(b)(i)	strain gauge	**B1**
9(b)(ii)	light-dependent resistor	**B1**

Question	Answer	Marks
10(a)	(induced) e.m.f. proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
10(b)	current in primary coil gives rise to magnetic flux	**B1**
	changing (magnetic) flux in core links with secondary coil	**B1**
	induced e.m.f. (in secondary coil) causes current in load/resistor	**B1**
10(c)	correct application of turns ratio: to peak voltage ratio, giving (V_0 / 220) = (450 / 2700) **or** to r.m.s. voltage ratio, giving ($V_{\text{r.m.s.}}$ / 156) = (450 / 2700)	**C1**
	correct application of √2 factor: to peak applied e.m.f., giving 220 / √2 **or** to peak output em.f., giving 37 / √2	**C1**
	$V_{\text{r.m.s.}}$ = 26 V	**A1**

Question	Answer	Marks
11(a)	packet/quantum of <u>energy</u>	**M1**
	of electromagnetic radiation	**A1**
11(b)(i)	$E = hc / \lambda$	**C1**
	$1.18 \times 1.60 \times 10^{-13} = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda$ $\lambda = 1.05 \times 10^{-12}$ m	**A1**
11(b)(ii)	$\lambda = h / p$ **or** $E = pc$	**C1**
	$p = (6.63 \times 10^{-34}) / (1.05 \times 10^{-12})$ **or** $p = (1.18 \times 1.60 \times 10^{-13}) / (3.00 \times 10^{8})$ leading to $p = 6.3 \times 10^{-22}$ N s	**B1**
11(c)	$6.3 \times 10^{-22} = 60 \times 1.66 \times 10^{-27} \times v$	**C1**
	$v = 6.3 \times 10^{3}$ m s^{-1}	**A1**

Question	Answer	Marks
12(a)	energy required to separate the nucleons (in a nucleus)	**M1**
	to infinity	**A1**
	or	
	energy released when nucleons come together (to form nucleus)	**(M1)**
	from infinity	**(A1)**
12(b)	mass defect = 140.911 – (57 × 1.007) – (84 × 1.009)	**C1**
	= 140.911 – 142.155 = (–)1.244 (u)	**C1**
	energy = $c^2(\Delta)m$	**C1**
	= $(3.00 \times 10^8)^2 \times 1.244 \times 1.66 \times 10^{-27}$ = 1.9×10^{-10} J	**A1**
12(c)(i)	$A = A_0e^{-\lambda t}$ **and** $\ln 2 = \lambda t_{½}$	**C1**
	$0.40 = \exp(-\ln 2 \times t / 3.9)$	**C1**
	or	
	$(0.5)^n = 0.40$	**(C1)**
	$n = 1.32$ **and** $t = 1.32 \times 3.9$	**(C1)**
	$t = 5.2$ hours	**A1**
12(c)(ii)	daughter product may be radioactive **or** random nature of decay	**B1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 2018**

MARK SCHEME

Maximum Mark: 100

Published

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 Cambridge Assessment International Education

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- 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:

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GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

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- 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.

Question	Answer	Marks
1(a)(i)	direction of force on a (small test) mass **or** path in which a (small test) mass will move	**B1**
1(a)(ii)	(at surface,) lines (of force) are radial	**B1**
	Earth has large radius/height above surface is small so lines are (approximately) parallel	**B1**
	parallel lines → constant field strength	**B1**
1(b)	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm/R$	**C1**
	$(m)v^2 = (m)(2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (1.7 \times 10^3 \times 10^3)$	**C1**
	$v = 2.4 \times 10^3\,\mathrm{m\,s^{-1}}$	**A1**
	correct conclusion based on comparison of v with $2.8\,\mathrm{km\,s^{-1}}$	**B1**
	or	
	(change in) KE of rock = (change in) PE	**(C1)**
	(at infinity) $E_P = (6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times m) / (1.7 \times 10^3 \times 10^3)$ $= 2.9 \times 10^6\,m$	**(C1)**
	E_K of rock $= \frac{1}{2} \times m \times (2.8 \times 10^3)^2 = 3.9 \times 10^6\,m$	**(A1)**
	correct conclusion based on comparison of E_K and E_P values	**(B1)**
	or	

Question	Answer	Marks
	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm/R$	**(C1)**
	$(m)\,(2800)^2 = (m)\,(2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22})\,/\,R$	**(C1)**
	$R = 1.3 \times 10^3$ km	**(A1)**
	correct conclusion based on <u>comparison</u> of R with 1.7×10^3 km	**(B1)**
	or	
	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm/R$	**(C1)**
	$(m)\,(2800)^2 = (m)\,(2 \times 6.67 \times 10^{-11} \times M)\,/\,(1.7 \times 10^6)$	**(C1)**
	$M = 1.0 \times 10^{23}$ kg	**(A1)**
	correct conclusion based on <u>comparison</u> of M with 7.4×10^{22} kg	**(B1)**

Question	Answer	Marks
2(a)	no intermolecular forces (so no potential energy)	**B1**
2(b)(i)	mean square speed (of molecule(s))	**B1**
2(b)(ii)	kelvin/thermodynamic/absolute <u>temperature</u>	**B1**
2(c)(i)1.	$pV = NkT$	**C1**
	$4.7 \times 10^{-2} \times 2.6 \times 10^5 = N \times 1.38 \times 10^{-23} \times 446$	**C1**
	or	
	$pV = nRT$ **and** $N = nN_A$ $4.7 \times 10^{-2} \times 2.6 \times 10^5 = n \times 8.31 \times 446$ $n = 3.3$ (mol)	**(C1)**
	$N = 3.3 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.0 \times 10^{24}$	**A1**
2(c)(i)2.	average increase $= 2900 / (2.0 \times 10^{24})$ $= 1.5 \times 10^{-21}$ J	**A1**
2(c)(ii)	$\Delta E_K = (3/2)k(\Delta)T$ $1.5 \times 10^{-21} = (3/2) \times 1.38 \times 10^{-23} \times (\Delta)T$	**C1**
	$(\Delta)T$ in range 70–72 K	**C1**
	$T = 173 + 273 + 70$ $= 520$ K	**A1**

Question	Answer	Marks
3(a)	(during melting,) bonds between atoms/molecules are broken	**B1**
	potential energy of atoms/molecules is increased	**B1**
	no/little work done so required input of energy is thermal	**B1**
3(b)(i)	(ΔQ =) $mc\Delta\theta$	**C1**
	loss = (160 × 0.910 × 15) + (330 × 4.18 × 15) = 2.3×10^4 J	**A1**
3(b)(ii)	2.3×10^4 = (48 × 2.10 × 18) + 48L + (48 × 4.18 × 23)	**C1**
	48L = 1.66×10^4 L = 350 J g^{-1}	**A1**

Question	Answer	Marks
4(a)	acceleration proportional to displacement	**B1**
	acceleration <u>directed</u> towards fixed point **or** displacement and acceleration in opposite <u>directions</u>	**B1**
4(b)(i)	**1.** amplitude decreases gradually so light damping **or** oscillations continue so light damping	**B1**
	2. loss of energy	**B1**
	due to friction in wheels **or** due to friction between wheels and surface (during slipping) **or** due to air resistance (on trolley)	**B1**
4(b)(ii)1.	$\omega^2 = 2k/m$	**C1**
	$= (2 \times 230)/0.950$	**C1**
	$\omega = 22\ \text{rad s}^{-1}$	**A1**
4(b)(ii)2.	$T = 2\pi/\omega$	**C1**
	$T = (2\pi/22) = 0.286\ \text{s}$ time $= 1.5T$ $= 0.43\ \text{s}$	**A1**

Question	Answer	Marks
5(a)(i)	range of frequencies (of signal)	B1
5(a)(ii)	advantage: e.g. better quality (of reproduction) greater rate of transfer of data less distortion	B1
	disadvantage: e.g. fewer stations (in any frequency range)	B1
5(b)(i)	5.0 V	A1
5(b)(ii)	maximum: 674 kHz	A1
	minimum: 626 kHz	A1
5(b)(iii)	$T = 1 / (10 \times 10^3) = 1.0 \times 10^{-4}$ s minimum time = $T / 2$ $= 5.0 \times 10^{-5}$ s	A1

Question	Answer	Marks
6(a)	capacitance = charge / potential	**M1**
	charge is (numerically equal to) charge on one plate	**A1**
	potential is potential difference between plates	**A1**
6(b)(i)	two in series, in parallel with the other (correct symbols)	**A1**
6(b)(ii)	two in parallel connected to one in series (correct symbols)	**A1**
6(c)(i)	capacitance = 1.2 μF	**A1**
6(c)(ii)	**1.** $Q = CV$	**C1**
	$= 1.2 \times 8.0$ $= 9.6\ \mu C$	**A1**
	2. $E = ½QV$ **and** $V = Q/C$ **or** $E = ½CV^2$ **and** $V = Q/C$ **or** $E = ½Q^2/C$	**C1**
	$E = ½(9.6 \times 10^{-6})^2/(3.0 \times 10^{-6})$ $= 1.5 \times 10^{-5}$ J	**A1**

Question	Answer	Marks
7(a)(i)	(fraction of) output is combined with the input	**M1**
	output (fraction) <u>subtracted/deducted</u> from input	**A1**
7(a)(ii)	Any two valid points e.g. • greater bandwidth/gain constant over a larger range of frequencies • smaller gain	**B2**
7(b)(i)	gain = 1 + (6400 / 800) = 9.0	**A1**
7(b)(ii)	**1.** (+)5.4 V	**A1**
	2. –9.0 V	**A1**
7(b)(iii)	replace the 6400 Ω resistor with a thermistor	**B1**

Question	Answer	Marks
8(a)	electric and magnetic fields at right-angles to one another *(may be shown on a clearly labelled diagram)*	**B1**
	particle enters fields (with velocity) normal to the (two) fields *(may be shown on a clearly labelled diagram)*	**B1**
	no deviation for particles with selected velocity	**B1**
8(b)	magnetic force equals/is the centripetal force	**C1**
	$Bqv = mv^2 / r$	**C1**
	$M = Bqr / v$ $= (94 \times 10^{-3} \times 1.6 \times 10^{-19} \times 0.075) / (3.4 \times 10^4)$	**M1**
	<u>division</u> by 1.66×10^{-27} shown, to give $m = 20$ u	**A1**
8(c)	sketch: semicircle clear (in same direction)	**B1**
	with larger radius	**B1**

Question	Answer	Marks
9(a)	(magnetic) flux density × area	**B1**
	magnetic flux density normal to area **or** reference to cross-sectional area **or** × sin (angle between *B* and *A*)	**B1**
	× number of turns on coil	**B1**
9(b)	e.m.f. = BAN / t **or** e.m.f = rate of change of flux <u>linkage</u>	**C1**
	$= (7.5 \times 10^{-3} \times \pi \times \{1.2 \times 10^{-2}\}^2 \times 160) / 0.15$ $= 3.6 \times 10^{-3}$ V	**A1**
9(c)	sketch: zero for 0–0.10 s, 0.25–0.35 s, and 0.425–0.55 s, and non-zero outside these ranges	**B1**
	two horizontal steps, with zero voltage either side	**B1**
	with same polarity	**B1**
	correct values (1st step 3.6 mV and 2nd step 7.2 mV)	**B1**

Question	Answer	Marks
10(a)	emission of electron	**B1**
	when electromagnetic radiation incident (on surface)	**B1**
10(b)(i)	packet/quantum/discrete amount of <u>energy</u>	**M1**
	of electromagnetic radiation	**A1**
10(b)(ii)	$E = hc/\lambda$	**C1**
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (420 \times 10^{-9})$ $= 4.7 \times 10^{-19}$ J	**A1**
10(b)(iii)	sodium: yes zinc: no	**B1**

Question	Answer	Marks
11(a)	X-ray image(s) taken of one slice	M1
	(many images) taken from different angles	A1
	(computer) produces 2D image of slice	B1
	(this is) repeated for (many) slices	M1
	to build up a 3D image (of structure)	A1
11(b)(i)	combining of images involves (very) large number of calculations	B1
11(b)(ii)	CT scan consists of (very) many (single X-ray) images	B1

Question	Answer	Marks
12(a)	emission of particles/radiation by unstable nucleus	**B1**
	spontaneous emission	**B1**
12(b)(i)	P – the curve that starts with a high number D – the curve with the peak S – the curve that increases from zero throughout *(one correct 1 mark, all three correct 2 marks)*	**B2**
12(b)(ii)	$\lambda t_{½} = 0.693$ $\lambda = 0.693 / (60.0 \times 60)$	**C1**
	$= 1.93 \times 10^{-4}\ \text{s}^{-1}$	**A1**
12(c)	half-life of F is much shorter than half-life of E	**B1**
	nuclei of F decay (almost) as soon as they are produced	**B1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **May/June 2018**

MARK SCHEME

Maximum Mark: 100

Published

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Question	Answer	Marks
1(a)	force proportional to product of masses and inversely proportional to square of separation	**B1**
	idea of force between point masses	**B1**
1(b)(i)	velocity changes/direction of motion changes/there is an acceleration/there is a resultant force so not in equilibrium	**B1**
1(b)(ii)1.	gravitational force equals/is centripetal force	**C1**
	$GMm / R^2 = mR\omega^2$ **and** $\omega = 2\pi / T$ **or** $Gm / R^2 = mv^2 / R$ **and** $v = 2\pi r / T$ **or** $GMm / R^2 = mR\,(2\pi / T)^2$	**M1**
	convincing algebra leading to $k = GM / 4\pi^2$	**A1**
1(b)(ii)2.	correct use of R^3 / T^2 for one planet (c gives 3.54×10^{21}; e and g both give 3.56×10^{21})	**C1**
	$3.5(5) \times 10^{21} = (6.67 \times 10^{-11} \times M) / 4\pi^2$ $M = 2.1 \times 10^{33}\,\text{kg}$	**A1**
	two or three values of R^3 / T^2 correctly calculated and used in a valid way to find a value for M based on more than one k	**B1**

Question	Answer	Marks
2(a)(i)	straight line through origin indicates acceleration $\propto$ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
2(a)(ii)	$a = -\omega^2 y$ **and** $\omega = 2\pi f$ $4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ *(or other valid read-off)*	C1
	$f = 3.8$ Hz	A1
2(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	B1
2(b)(ii)	(just leaves plate when) acceleration = 9.81 m s^{-2}	C1
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ **or** $9.81 = 563 \times y_0$	C1
	amplitude = 17 mm	A1

Question	Answer	Marks
3(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	**B1**
	(energy of) molecules/atoms/particles in random motion	**B1**
3(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	**B1**
	internal energy is (solely) kinetic energy (of particles)	**B1**
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	**B1**
3(b)	$pV = NkT$	**C1**
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 298$	**C1**
	or	
	$pV = nRT$ **and** $N = n \times N_A$	**(C1)**
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 298$ $n = 46.5$ (mol) $N = 46.5 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.8 \times 10^{25}$	**A1**

Question	Answer	Marks
4(a)	e.g. microphone weighing scales/pressure sensor lighters/spark generation watches/clocks/regulation of time	**B1**
4(b)	<u>pulses</u> (of ultrasound)	**B1**
	reflected at boundaries (between media)	**B1**
	(reflected pulses) detected by (ultrasound) generator	**B1**
	Any three from: • time delay (between transmission and receipt) gives information about depth (of boundary) • intensity of reflected pulse gives information about (nature of) <u>boundary</u> • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	**B3**

Question	Answer	Marks
5(a)(i)	west to east	**B1**
5(a)(ii)	above the Equator	**B1**
5(a)(iii)	value in range (1–300) $\times 10^9$ Hz	**A1**
5(b)(i)	gain / dB = 10 lg (P_2 / P_1)	**C1**
	–195 = 10 lg (P / 3000) **or** 195 = 10 lg (3000 / P)	**C1**
	power = 9.5×10^{-17} W	**A1**
5(b)(ii)	up-link has been (greatly) attenuated (before reaching satellite) **or** down-link signal must be (greatly) amplified (before transmission back to Earth) **or** up-link has (much) smaller intensity/power than down-link	**B1**
	(different frequency) prevents down-link (signal) swamping up-link (signal)	**B1**

Question	Answer	Marks
6(a)	force per unit charge	**B1**
6(b)	$E = Q / (4\pi\varepsilon_0 r^2)$	**C1**
	$2.0 \times 10^4 = Q / (4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$ charge = 1.5×10^{-7} C	**A1**
6(c)	charge (= Q [52 / 26]^2) = 4Q	**C1**
	additional charge = 3Q	**A1**

Question	Answer	Marks
7(a)	(capacitance =) charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
7(b)(i)	4.5×10^{-6} C	A1
7(b)(ii)	9.0×10^{-8} C	A1
7(b)(iii)	capacitance = (9.0×10^{-8}) / 120	C1
	= 7.5×10^{-10} F	A1
7(c)	total capacitance is halved	B1
	current is halved	B1

Question	Answer	Marks
8(a)(i)	(fraction of) output is combined with the input	**M1**
	output (fraction) subtracted/deducted from input	**A1**
8(a)(ii)	any two valid points e.g.: • greater bandwidth/gain constant over a larger range of frequencies/greater bandwidth • smaller gain	**B2**
8(b)(i)	gain = (–)9600 / 800	**C1**
	= –12	**A1**
8(b)(ii)	**1.** 1.2 V	**B1**
	2. –6 V	**B1**
8(b)(iii)	replace the 9600 Ω resistor with an LDR	**B1**

Question	Answer	Marks
9(a)	using Fleming's left-hand rule force on wire is upwards	**B1**
	by Newton's third law, force on magnet is downwards	**B1**
9(b)(i)	$F = BIL$	**C1**
	$= 3.7 \times 10^{-3} \times 5.1 \times 8.5 \times 10^{-2}$ $= 1.6 \times 10^{-3}$ N	**A1**
9(b)(ii)	$F = 1.6 \times 10^{-3}$ N	**A1**
9(c)	sketch: sinusoidal wave with two cycles	**B1**
	amplitude 2.3×10^{-3} N	**B1**
	period 0.05 s	**B1**

Question	Answer	Marks
10(a)	induced <u>e.m.f.</u> proportional to rate	**M1**
	of <u>change</u> of (magnetic) <u>flux</u> (linkage) **or** of <u>cutting</u> (magnetic) <u>flux</u>	**A1**
10(b)	current in coil produces flux	**B1**
	(by Faraday's law) changing flux induces e.m.f. in ring	**B1**
	current in ring causes field (around ring)	**B1**
	(by Lenz's law) field around ring opposes field around coil	**B1**

Question	Answer	Marks
11(a)(i)	packet/quantum/discrete amount of <u>energy</u>	**M1**
	of electromagnetic radiation	**A1**
11(a)(ii)	(maximum) energy of emitted electrons is independent of intensity **or** no emission of electrons below the threshold frequency regardless of intensity **or** no emission of electrons when photon energy is less than work function (energy) regardless of intensity	**B1**
11(b)	in darkness: conduction band empty so high resistance	**B1**
	in daylight: electrons in valence band absorb photons	**B1**
	in daylight: electrons 'jump' to conduction band	**B1**
	this leaves holes in valence band	**B1**
	more charge carriers in daylight so resistance decreases	**B1**

Question	Answer	Marks
12(a)(i)	$I = I_0 e^{-\mu x}$	**C1**
	$= I_0 \exp(-0.90 \times 2.8)$ $= 0.080\, I_0$	**A1**
12(a)(ii)	$I = I_0 \exp[(-0.90 \times 1.5) \times (-3.0 \times 1.3)]$	**C1**
	$= I_0\ (0.259 \times 0.20)$ $= 0.0052\, I_0$	**A1**
12(b)(i)	difference in degrees of blackening	**M1**
	between structures	**A1**
12(b)(ii)	large difference in intensities so good contrast	**B1**

Question	Answer	Marks
13(a)	emission of particles/radiation by unstable nucleus	**B1**
	spontaneous emission	**B1**
13(b)(i)	use of graph to determine half-life = 14 minutes	**B1**
	hence $\lambda = \ln 2 / (14 \times 60)$ (s^{-1})	**C1**
	N at 14 minutes = 4.4×10^7 **and** $A = \lambda N$	**C1**
	activity $= 4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ $= 3.6 \times 10^4$ Bq	**A1**
	or	
	correct tangent drawn at time t = 14 minutes	**(B1)**
	magnitude of gradient of tangent identified as activity	**(C1)**
	correct working for gradient leading to activity	**(C1)**
	activity = 3.6×10^4 Bq	**(A1)**
13(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ **or** $\lambda = \ln 2 / (14.0 \times 60)$	**C1**
	$\lambda = 8.2 \times 10^{-4}\ s^{-1}$	**A1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **May/June 2019**

MARK SCHEME

Maximum Mark: 100

Published

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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.

Question	Answer	Marks
1(a)	(F =) GMm / x^2, where G is the (universal) gravitational constant	**B1**
1(b)(i)	$GMm / x^2 = mv^2 / x$ **or** $v^2 = GM / x$	**C1**
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$ so $v = 3.7 \times 10^3$ m s^{-1}	**A1**
1(b)(ii)	potential energy = (–)GMm / x	**C1**
	E_A = (–)$(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (3.64 \times 10^6)$ **or** E_B = (–)$(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (5.00 \times 10^7)$	**M1**
	correct substitution and subtraction $E_B - E_A$ shown, leading to $\Delta E_p = 8.3 \times 10^9$ J	**A1**
	or	
	ϕ = (–)GM / x **and** potential energy = $m\phi$	**(C1)**
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1 / (3.64 \times 10^6)) - (1 / (5.00 \times 10^7))]$ (= 1.27×10^7 J kg^{-1})	**(M1)**
	$\Delta E_p = 1.27 \times 10^7 \times 650$ $= 8.3 \times 10^9$ J	**(A1)**
1(c)	kinetic energy <u>or</u> potential energy decreases	**B1**
	kinetic energy <u>and</u> potential energy decrease so total energy decreases	**B1**

Question	Answer	Marks
2(a)(i)	$pV = nRT$	C1
	$n = (3.0 \times 10^5 \times 210 \times 10^{-6}) / (8.31 \times 270)$	C1
	$= 0.028$ mol	A1
2(a)(ii)	$V \propto T$ **or** $T = pV / nR$ with value of n from **(i)**	C1
	$T = (140 / 210) \times 270$ **or** $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$ $= 180$ K	A1
2(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	C1
	$= 21$ J	A1

Question	Answer	Marks
2(b)	$\Delta U = w + q$	**C1**
	$= 21 - 53$	**C1**
	or	
	$\Delta U = (nN_A) \times (3/2)k\Delta T$	**(C1)**
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	**(C1)**
	or	
	$\Delta U = (3/2)nR\Delta T$	**(C1)**
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	**(C1)**
	$\Delta U = (-)32$ J	**A1**

Question	Answer	Marks
3(a)(i)	amplitude = 0.020 m	A1
3(a)(ii)	T = 0.60 s	C1
	f = 1 / T = 1.7 Hz	A1
3(a)(iii)	$a = (–)\omega^2 x$ **and** [$\omega = 2\pi f$ **or** $\omega = 2\pi / T$]	C1
	$a = (4\pi^2 / 0.60^2) \times 2.0 \times 10^{–2}$ $= 2.2\ \text{m s}^{–2}$	A1
3(b)	$1.67 = (1 / 2\pi) \times [(24 \times 10^{–4} \times \rho \times 9.81) / 0.23]^{1/2}$	C1
	$\rho = 1.1 \times 10^3\ \text{kg m}^{–3}$	A1
3(c)	wave starting with a peak at (0,6)	B1
	wave with same period (or slightly greater)	B1
	peak height decreasing successively	B1

Question	Answer	Marks
4(a)(i)	loss of (signal) power/amplitude/intensity	**B1**
4(a)(ii)	unwanted/random signal	**B1**
	superposed on (transmitted) signal	**B1**
4(b)	noise can be eliminated (from digital signals) **or** signal can be regenerated (from digital signals)	**B1**
4(c)(i)	010<u>1</u>	**A1**
4(c)(ii)	1000 at t = 4.0 ms	**B1**
	0110 at t = 5.0 ms **and** 0100 at t = 6.0 ms	**B1**
4(d)	series of equally-spaced steps of width 1 ms	**B1**
	each step in correct time interval (0–1 ms, 1–2 ms, 2–3 ms, 3–4 ms)	**B1**
	correct step heights (2, 6, 4 and 5)	**B1**

Question	Answer	Marks
5(a)	force per unit charge	**B1**
	(force on) positive charge	**B1**
5(b)(i)	field changes <u>direction</u> (between A and B)/field is zero at a point (between A and B)	**M1**
	so charges have same sign	**A1**
5(b)(ii)	Any one from: • field is (also) influenced by charge B • charge A is not isolated/is not the only charge present • field is due to two/both charges • field is the resultant of two fields	**B1**
5(b)(iii)	$E = Q / (4\pi\varepsilon_0 x^2)$	**C1**
	at x = 10 cm, $E_A = E_B$	**C1**
	$Q_A / 10^2 = Q_B / 5^2$ $Q_A / Q_B = 4.0$	**A1**

Question	Answer	Marks
6(a)	Any valid two points e.g.: • to store (electrical) energy • smoothing/reduce ripple (on direct voltages/currents) • to block d.c. • timing/time delay (circuits) • in oscillator (circuits) • in tuning (circuits) • to prevent arcing/sparks	**B2**
6(b)	clear indication of equal charge on each capacitor	**B1**
	$E = V_1 + V_2 + V_3$ **and** $V = Q / C$	**M1**
	completion of algebra leading to $1 / C = 1 / C_1 + 1 / C_2 + 1 / C_3$	**A1**
6(c)(i)	three capacitors connected in parallel	**B1**
6(c)(ii)	parallel combination of three capacitors connected in series with one capacitor	**B1**

Question	Answer	Marks
7(a)(i)	(amplifier) gain is very large/infinite	**B1**
	for amplifier not to saturate, $V^+ = V^-$ **or** feedback (loop) ensures $V^+ = V^-$	**B1**
	V^+ is at earth/0 V so V^- is (almost) at earth/0 V	**B1**
7(a)(ii)	gain = (–)5200 / 800 **or** (–)5.2 / 0.80	**C1**
	= –6.5	**A1**

Question	Answer	Marks
7(b)	(at saturation,) $V_{OUT} = 5\text{ V}$	**C1**
	p.d. across R = 5 – 2.3 = 2.7 (V)	**C1**
	resistance = $2.7 / (30 \times 10^{-3})$ = 90 Ω	**A1**
	or	
	$R_{diode} = 2.3 / 0.030 = 77\ \Omega$ $R_{total} = 5.0 / 0.030 = 167\ \Omega$	**(C1)**
	$R_{resistor}$ (= 167 – 77) = 90 Ω	**(A1)**
	or	
	$R_{diode} = 2.3 / 0.030 = 77\ \Omega$ $77 / (R_{resistor} + 77) \times 5 = 2.3$	**(C1)**
	$R_{resistor} = 90\ \Omega$	**(A1)**
	or	
	$R_{diode} = 2.3 / 0.030 = 77\ \Omega$ $R_{resistor} = 77 \times (2.7 / 2.3)$	**(C1)**
	$R_{resistor} = 90\ \Omega$	**(A1)**

Question	Answer	Marks
8(a)(i)	region where a force is exerted on: a magnetic pole **or** a moving charge **or** a current-carrying wire	**B1**
8(a)(ii)	arrow on axis of solenoid pointing downwards labelled P	**B1**
8(b)(i)	<u>direction</u> of induced e.m.f./current	**M1**
	(tends to) oppose the change causing it	**A1**
8(b)(ii)	magnetic field in solenoid is increasing	**B1**
	field in coil in opposite direction to oppose increase	**B1**
	arrow inside or just above small coil pointing in opposite direction to P	**B1**
8(c)	e.m.f. $= N\Delta\phi / \Delta t$	**C1**
	$= (75 \times 1.4 \times 10^{-3} \times 2 \times 7.0 \times 10^{-4}) / 0.12$	**C1**
	$= 1.2 \times 10^{-3}$ V	**A1**

Question	Answer	Marks
9(a)	nuclei precess	**B1**
	precession is about direction of magnetic field	**B1**
	frequency of precession depends on field strength **or** frequency of precession is in radio-frequency range	**B1**
9(b)	Any two points from: • frequency (of precession) depends on position • to locate position of (spinning) nuclei • to change region where nuclei are detected	**B2**

Question	Answer	Marks
10(a)	V_{MAX} = 15 V	**A1**
10(b)	$210 = 2\pi / T$	**C1**
	T = 0.0299 s	**C1**
	$(t_2 - t_1)$ = 0.060 s	**A1**

Question	Answer	Marks
11(a)	Any three points from: • (max) energy of emitted electrons depends on frequency • (max) energy of emitted electrons does not depend on intensity • rate of emission of electrons depends on intensity (at constant frequency) • existence of frequency below which no emission of electrons • instantaneous emission of electrons • increasing the frequency at constant intensity decreases the rate of emission of electrons	B3
11(b)(i)	photon energy $= hc / \lambda$	C1
	$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (380 \times 10^{-9})$ $(= 5.23 \times 10^{-19}$ J)	C1
	= 3.3 eV	A1
11(b)(ii)	photon energy must be greater than work function (energy)	B1
	so sodium and calcium	B1
11(c)	$\lambda = h / p$	C1
	$p = (6.63 \times 10^{-34}) / (380 \times 10^{-9})$ $= 1.74 \times 10^{-27}$ N s	C1
	force $= 1.74 \times 10^{-27} \times 7.6 \times 10^{14}$ $= 1.3 \times 10^{-12}$ N	A1

Question	Answer	Marks
12(a)(i)	$\Delta N / \Delta T$	**B1**
12(a)(ii)	$\Delta N / N$	**B1**
12(a)(iii)	$\Delta N / (N\,\Delta T)$	**B1**
12(b)(i)	**1.** mass change = 5.60×10^{-3} u	**A1**
	2. energy = $(\Delta)mc^2$	**C1**
	$= 5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $(= 8.36 \times 10^{-13}$ J$)$	**C1**
	= 0.84 pJ	**A1**
12(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	**B1**
	energy of γ-ray photon	**B1**

Cambridge International AS & A Level

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **October/November 2021**

MARK SCHEME

Maximum Mark: 100

Published

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This document consists of **15** printed pages.

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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	<u>'List rule' guidance</u> 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.

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 independent 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 method 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 compensatory 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 answer 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. Within 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 =) $NkT = ⅓Nm\langle c^2 \rangle$ **or** $pV = NkT$ **and** $pV = ⅓Nm\langle c^2 \rangle$	**M1**
	leading to $½m\langle c^2 \rangle = (3/2)kT$ and $½m\langle c^2 \rangle = E_K$	**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 $-7.9\ \text{cm s}^{-1}$ <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 $\pm$ 34 V (*1 mark out of 2 awarded if peak E shown as* $\pm$ 17 V *or* $\pm$ 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 $\times$ 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**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **October/November 2020**

MARK SCHEME

Maximum Mark: 100

Published

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

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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).
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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.

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. Within 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)(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

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

Question	Answer	Marks
2(a)	+*q*: thermal energy transfer to system	B1
	+*w*: work done on system	B1
2(b)(i)	(W =) $2.6 \times 10^5 \times (3.8 - 2.3) \times 10^{-3} = 390$ 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 complete correct answer: change | q / J | w / J | ΔU / J A to B | (+)1370 | –390 | (+)980 B to C | 0 | (+)550 | (+)550 C to A | –1530 | 0 | –1530	B1

Question	Answer	Marks
3(a)	acceleration (directly) proportional to displacement	**B1**
	acceleration in opposite direction to displacement **or** acceleration (directed) towards equilibrium position	**B1**
3(b)	$v = \omega(x_0^2 - x^2)^{½}$ **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**
	$f = 0.45$ Hz	**A1**
3(c)	$1 / 0.45 = 2\pi \times (L / 9.81)^{½}$	**C1**
	$L = 1.2$ 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**

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 dB	**A1**

Question	Answer	Marks
5(a)	work done per unit charge	**B1**
	(work done on charge) moving positive charge from infinity	**B1**
5(b)(i)	$(2.0 \times 10^{-9}) / 4\pi\varepsilon_0(4.0 \times 10^{-2}) + Q / 4\pi\varepsilon_0(8.0 \times 10^{-2}) = 0$	**C1**
	$Q = 4.0 \times 10^{-9}$ 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**
	$v = 3.4 \times 10^5$ 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: • smoothing • timing/(time) delay • tuning • oscillator • blocking d.c. • surge protection • temporary power supply	**B3**
6(b)	(capacitors in series have combined capacitance =) 8 μF	**C1**
	capacitance = 8 + 24 = 32 μF	**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 Ω	**A1**
7(b)(ii)	non-zero value less than 1000 Ω	**A1**

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**
	$= 1.4 \times 10^{-12}$ 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**

Question	Answer	Marks
9(a)	flux density × area	**M1**
	where flux is normal to area	**A1**
	or	
	flux density × area × sin θ	**(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**

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**

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**
	$p = (6.63 \times 10^{-34}) / (544 \times 10^{-9})$ $= 1.22 \times 10^{-27}$ N s	**A1**
11(b)(ii)	energy $= hc / \lambda$	**C1**
	$= 6.63 \times 10^{-34} \times 3.00 \times 10^{8} \times (540^{-1} - 544^{-1}) \times 10^{9}$ $= 2.7 \times 10^{-21}$ J	**A1**
11(c)	(smaller wavelength corresponds to) greater photon energy	**B1**
	any one point from: • (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**

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**
	$560 = 9.9 \times 10^{-7} \times N$ $N = 5.7 \times 10^{8}$	**A1**
12(c)	$A = A_0\ e^{-\lambda t}$ $170 = 560 \exp(-9.9 \times 10^{-7} \times t)$	**C1**
	$t = 1.2 \times 10^{6}$ s	**C1**
	= 14 days	**A1**

Cambridge International AS & A Level

PHYSICS	**9702/42**
Paper 4 A Level Structured Questions	**March 2020**
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Examples of how to apply the list rule

State **three** reasons…. [3]

A

1	Correct	✓	**2**
2	Correct	✓	
3	Wrong	×	

B
(4 responses)

1	Correct, Correct	✓, ✓	**3**
2	Correct	✓	
3	Wrong	ignore	

C
(4 responses)

1	Correct	✓	**2**
2	Correct, Wrong	✓, ×	
3	Correct	ignore	

D
(4 responses)

1	Correct	✓	**2**
2	Correct, CON (of 2.)	×, (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.)	× (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	×	
3	CON (of 2.) Correct	(discount 2) ✓	

I
(4 responses)

1	Correct	✓	**2**
2	Correct	×	
3	Correct CON (of 2.)	✓ (discount 2)	

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.
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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.
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Question	Answer	Marks
1(a)	work done per unit mass	B1
	work done moving mass from infinity (to the point)	B1
1(b)(i)	gravitational force provides centripetal force	C1
	$mv^2 / r = GMm / r^2$ and $v = 2\pi r / T$ OR $mr\omega^2 = GMm / r^2$ and $\omega = 2\pi / T$ OR $r^3 = GMT^2 / 4\pi^2$	C1
	$r^3 = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times (13.7 \times 24 \times 3600)^2 / 4\,\pi^2$ so r = 2.4×10^8 m	A1
1(b)(ii)	(E_P = –) GMm / r work done = $GMm / r_1 - GMm / r_2$	C1
	= $6.67 \times 10^{-11} \times 360 \times 6.0 \times 10^{24}$ ($1/6.4 \times 10^6 - 1 / 2.4 \times 10^8$)	C1
	= **2.2×10^{10}** J	A1
1(b)(iii)	$g = GM / r^2$	C1
	ratio = $r_{TESS}{}^2 / r_{earth}{}^2$ = $(2.4 \times 10^8 / 6.4 \times 10^6)^2$ = **1400**	A1

Question	Answer	Marks
2(a)	n = 110 / 0.032 or 110000 / 32 or 3440	**C1**
	$pV = nRT$	**C1**
	$T = (1.0 \times 10^5 \times 85) / (8.31 \times (110 / 0.032)) = 300$ K	**A1**
2(b)	$E = mc\Delta\theta$ $= 110 \times 0.66 \times 50$	**C1**
	= **3600** J	**A1**
2(c)	Any 3 from: • molecule collides with wall • momentum of molecule changes during collision (with wall) • force on molecule so force on wall • many forces act over surface area of container exerting a pressure	**B3**
2(d)	$KE \propto T$ $v \propto \sqrt{T}$	**C1**
	ratio $= \sqrt{(350 / 300)}$ = **1.1**	**A1**

Question	Answer	Marks
3(a)(i)	**0.050** m	**A1**
3(a)(ii)	$\omega = v_o / x_o$	**C1**
	$T = 2\pi / \omega$ $0.42 = (2\pi \times 0.050) / T$	**C1**
	T = **0.75** s	**A1**
3(a)(iii)	one point labelled P where ellipse crosses displacement axis marked	**A1**
3(b)(i)	(induced) e.m.f. proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
3(b)(ii)	(there is) current in the circuit	**B1**
	either	
	current causes thermal energy (dissipated) in resistor	**B1**
	thermal energy comes from energy of magnet	**B1**
	or	
	current causes magnetic field around coil	**(B1)**
	two fields cause an opposing force on magnet	**(B1)**

Question	Answer	Marks
4(a)(i)	Any 2 from: • allows the reflected signal to be distinguished from the emitted signal • detection occurs in the time between emitted pulses • (reflection of ultrasound) detected by same probe / transducer / crystal • cannot emit and detect at same time (hence pulses)	**B2**
4(a)(ii)	piezo-electric crystal	**B1**
	ultrasound makes crystal vibrate / resonate	**B1**
	vibration produces (alternating) e.m.f. / p.d. across crystal	**B1**
4(b)(i)	$= (1.6 \times 10^6 - 4.3 \times 10^2)^2 / (1.6 \times 10^6 + 4.3 \times 10^2)^2$ = **0.999**	**B1**
4(b)(ii)	without the gel most of the ultrasound is reflected	**B1**
	Z values more similar / α reduces so less (ultrasound) is reflected / more (ultrasound) is transmitted	**B1**

Question	Answer	Marks
5(a)	Any 2 from: • noise can be filtered out / noise can be removed / signal can be regenerated • can carry more information per unit time / greater rate of transmission of data • can have extra bits of data to check for errors • can be encrypted	**B2**
5(b)(i)	$v \propto \lambda$	**C1**
	ratio $= v_{air} / v_{fibre}$ $= 3.00 \times 10^8 / 2.07 \times 10^8$ $= \mathbf{1.45}$	**A1**
5(b)(ii)	attenuation = 10 log (P_2/P_1)	**C1**
	$0.40 \times L = 10 \log (1.5 / 0.06)$ $0.40 \times L = 13.979$	**C1**
	$L =$ **35** km	**A1**

Question	Answer	Marks
6(a)	**2.0** cm	**B1**
6(b)	At 16 (cm) from A the electric fields are equal or $E_A = E_B$	**B1**
	$E = Q / 4\pi\varepsilon_o r^2$ $Q_A / (4\pi\varepsilon_o r_A{}^2) = Q_B / (4\pi\varepsilon_o r_B{}^2)$ $3.6 \times 10^{-9} / 0.16^2 = Q_B / 0.08^2$	**C1**
	Q_B = $\mathbf{9.0 \times 10^{-10}}$ C	**A1**
6(c)(i)	$V = Q / 4\pi\varepsilon_o r_A$ $V = 3.6 \times 10^{-9} / (4 \times \pi \times 8.85 \times 10^{-12} \times 0.020)$	**C1**
	V = **1600** V	**A1**
6(c)(ii)	$C = Q / V$ $= 3.6 \times 10^{-9} / 1600$	**C1**
	= $\mathbf{2.3 \times 10^{-12}}$ F	**A1**

Question	Answer	Marks
7(a)	axes labelled with resistance and temperature	**M0**
	concave curve not touching temperature axis	**A1**
	line with negative gradient throughout	**A1**
7(b)	resistance of thermistor decreases	**B1**
	total circuit resistance decreases so voltmeter reading increases *or* current increases so voltmeter reading increases *or* greater proportion of resistance in fixed resistor so voltmeter reading increases *or* p.d. across thermistor decreases so voltmeter reading increases	**B1**
7(c)	(0.020 strain means) $\Delta R / R = 0.090$	**C1**
	$\Delta R = 0.090 \times 120 = 10.8\ \Omega$	**C1**
	resistance = 120 + 10.8 = **130** Ω	**A1**

Question	Answer	Marks
8(a)	a region where a magnet / magnetic material / moving charge / current carrying conductor experiences a force	**B1**
8(b)	$B = F / Il$ e.g. $= 9 \times 10^{-3} / (5.0 \times 0.045)$	**C1**
	= **0.040** T	**A1**
8(c)(i)	force is (always) perpendicular to the velocity / direction of motion	**B1**
	magnetic force provides the centripetal force *or* force perpendicular to motion causes circular motion	**B1**
	magnitude of force (due to the magnetic field) is constant *or* no work done by force *or* the force does not change the speed	**B1**
8(c)(ii)	Applying the list rule, any 2 from: accelerating p.d. radius of path / radius of semicircle magnetic flux density	**B2**

Question	Answer	Marks
9(a)(i)	9.0 / √2 = **6.4** V	**A1**
9(a)(ii)	ω = 20 $\omega = 2\pi / T$ $T = 2\pi / 20$	**C1**
	T = **0.31** s	**A1**
9(b)	the r.m.s. voltages are different, so no	**B1**
9(c)(i)	$P = V_{\text{r.m.s.}} \times I_{\text{r.m.s.}}$	**C1**
	= 120 × 0.64 = 76.8 W	**C1**
	efficiency = (76.8 / 80) × 100 = **0.96** or **96** %	**A1**
9(c)(ii)	Any one from: • heat losses due to resistance of windings / coils • heat losses in magnetising and demagnetising core / hysteresis losses in core • heat losses due to eddy currents in (iron) core • loss of flux linkage	**B1**

Question	Answer	Marks
10(a)	energy of a photon required to remove an electron	**B1**
	either: energy to remove electron from a surface *or*: minimum energy to remove electron *or*: energy to remove electron with zero kinetic energy	**B1**
10(b)(i)	Correct read off from graph of f as 5.45×10^{14} Hz when $E_{MAX} = 0$ $5.45 \times 10^{14} \times 6.63 \times 10^{-34}$	**C1**
	= $\mathbf{3.6 \times 10^{-19}}$ J	**A1**
10(b)(ii)	$3.6 \times 10^{-19} / 1.6 \times 10^{-19} = 2.3$ eV so potassium	**A1**
10(c)(i)	each photon has same energy so no change	**B1**
10(c)(ii)	more photons (per unit time) so (rate of emission) increases	**B1**

Question	Answer	Marks
11(a)	$eV = hf$ $f = 1.60 \times 10^{-19} \times 100\,000 / 6.63 \times 10^{-34}$	C1
	$= \mathbf{2.41 \times 10^{19}}$ Hz	A1
11(b)	(aluminium filter) absorbs (most) low energy X-rays	B1
	Any 2 from • X-ray beam contains many wavelengths • so low energy X-rays are not absorbed in the body • low energy X-rays can can cause harm but do not contribute to the image	B2
11(c)(i)	$I / I_0 = e^{-\mu x}$ $e^{-0.23 \times 0.80} = 0.83$	C1
	17% absorbed	A1
11(c)(ii)	bone is seen as lighter / muscle is seen as darker	B1
	either bone has a higher μ value so absorbs more *or* muscle has a lower μ value so transmits more	B1

Question	Answer	Marks
12(a)	(minimum) energy required to separate the nucleons	**M1**
	to infinity	**A1**
12(b)(i)	**37** **2**	**B1**
12(b)(ii)	fission	**B1**
12(b)(iii)	binding energy per nucleon smaller for U than for Cs	**B1**
12(c)	Current ratio 2 Y to 1 Zr, so initially 3 Y $2 = 3\,e^{-\lambda t}$ $\lambda = 0.693 / 2.7$	**C1**
	$\ln(2/3) = -(\ln 2 / 2.7)t$	**C1**
	t = **1.6** days	**A1**
	or	
	$(½)^n = 2/3$	**(C1)**
	n = 0.585	**(C1)**
	time = 0.585 × 2.7 = **1.6** days	**(A1)**

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.

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

This document consists of **19** 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.

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	<u>'List rule' guidance</u> 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 rule

State **three** reasons…. [3]

A

1. Correct	✓	**2**
2. Correct	✓	
3. Wrong	×	

B (4 responses)

1. Correct, Correct	✓, ✓	**3**
2. Correct	✓	
3. Wrong	ignore	

C (4 responses)

1. Correct	✓	**2**
2. Correct, Wrong	✓, ×	
3. Correct	ignore	

D (4 responses)

1. Correct	✓	**2**
2. Correct, CON (of 2.)	×, (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.)	× (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	×	
3. CON (of 2.) Correct	(discount 2) ✓	

I (4 responses)

1. Correct	✓	**2**
2. Correct	×	
3. Correct CON (of 2.)	✓ (discount 2)	

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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**
	$M = \dfrac{4 \times \pi^2 \times 1.2 \times 10^{34}}{6.67 \times 10^{-11} \times 2.4 \times (365 \times 24 \times 3600)^2}$	**C1**
	$= 3.0 \times 10^{30}$ 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)	$\dfrac{GMm}{r^2} = \dfrac{mv^2}{r}$ *OR* $v^2 = \dfrac{GM}{r}$ *OR* $v = \sqrt{\dfrac{GM}{r}}$	**M1**
	use of ½ mv^2 (e.g. multiplication by ½ m) leading to $\dfrac{GMm}{2r}$	**A1**
1(c)(iii)	Ep = $\phi\, m$ <u>and</u> $\phi = \dfrac{-GM}{r}$ or $E_p = \dfrac{-GMm}{r}$ Total energy = $E_k + E_p$	**C1**
	Total energy $= \dfrac{GMm}{2r} + \dfrac{-GMm}{r} = \dfrac{-GMm}{2r}$	**A1**

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

Question	Answer	Marks
2(b)	$c^2 = \dfrac{3\times 2.0\times 10^{23}\times 1.38\times 10^{-23}\times(294+84)}{2.0\times 10^{23}\times 40\times 1.66\times 10^{-27}}$ $c^2 = 236\,000$ $c = 485$	C1
	$ratio\left(=\dfrac{485}{430}\right) = 1.1$	A1
	OR $v \propto \sqrt{T}$ or $v^2 \propto T$	(C1)
	$ratio = \sqrt{\dfrac{273+21+84}{273+21}}$ or $\sqrt{\dfrac{378}{294}}$ ratio = **1.1**	(A1)

Question	Answer	Marks
3(a)	Any 2 from: • 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 × time = 150 × 5.5 × 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)	$a = \frac{F}{m}$ $= \frac{0.77}{0.25}$ $= 3.1 m s^{-2}$	**A1**
4(b)(iii)	$a = -\ \omega^2 x$ $\omega\ = \sqrt{\frac{3.1}{0.048}}$ $\omega = 8.04$	**C1**
	$T = 2\ \pi / \omega$	**C1**
	$T = 2\pi / 8.04$ $= 0.78$ 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: • 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)	$\lambda = \frac{v}{f}$ $= \frac{3.0\times10^8}{1.5\times10^6} = 200\,m$	**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)	$E = \frac{Q}{4\pi\varepsilon_o r^2}$ e.g. r = 2.1 cm, E = 1.30 × 10^5 V m^{-1} $Q = 4\pi\varepsilon_o r^2 E$ $= 4\times\pi\times8.85\times10^{-12}\times0.021^2\times1.30\times10^5$	**C1**
	$= 6.4\times10^{-9}C$	**A1**

Question	Answer	Marks
6(c)	$C = \dfrac{Q}{V}$ *either* $V = \dfrac{Q}{4\pi\varepsilon_o r}$ leading to $C = 4\pi\varepsilon_o r$	C1
	$C = 4 \times \pi \times 8.85 \times 10^{-12} \times 0.021$	C1
	$(C =) 2.3 \times 10^{-12}$ F	A1
	or $V = \dfrac{Q}{4\pi\varepsilon_o r}$ $= \dfrac{6.4 \times 10^{-9}}{4 \times \pi \times 8.85 \times 10^{-12} \times 0.021}$ $= 2740 V$ $C = \dfrac{6.4 \times 10^{-9}}{2740}$	(C1)
	$= 2.3 \times 10^{-12}$ F	(A1)

Question	Answer	Marks
7(a)(i)	non-inverting (amplifier)	**B1**
7(a)(ii)	$\text{gain} = \dfrac{R_f}{R} + 1$ $\text{gain} = \dfrac{3.6}{0.72} + 1 = 6.0$	**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**

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: • protons de-excite • protons emit r.f. pulses • emitted (r.f.) pulse (from proton) detected	**B1**

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

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)	$\omega = 100\pi$ $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{100\pi}$	**C1**
	$= 0.020\,s$	**A1**
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 = $1.6 \times 10^{-19} \times 15000$ = 2.4×10^{-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)	μ = – gradient *or* ln $(I / I_o) = -\mu x$	**C1**
	(e.g. 2.08 / 10.0) = **0.21** cm^{-1}	**A1**

Question	Answer	Marks
11(b)(ii)	$\ln(0.05) = -\mu x$	**C1**
	$x = \dfrac{\ln 0.05}{-\mu}$ *e.g.* $x = 14\,cm$	**A1**

Question	Answer	Marks
12(a)	1 not affected by external factors	**B1**
	2 cannot predict when a (particular) nucleus will decay *or* cannot predict which nucleus will decay (next)	**B1**
12(b)(i)	Number of atoms = $\dfrac{1.0\times10^{-9}}{90\times1.66\times10^{-27}}$ *or* $\dfrac{1.0\times10^{-9}\times6.02\times10^{23}}{90\times10^{-3}}$ $= 6.693\times10^{15}$	**C1**
	$A = \lambda N$ $\lambda = \dfrac{5.2\times10^{6}}{6.693\times10^{15}}$	**C1**
	$\lambda = 7.8\times10^{-10}\ \text{s}^{-1}$	**A1**
12(b)(ii)	daughter nucleus is unstable	**B1**

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **March 2019**

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 March 2019 series for most Cambridge IGCSE™, Cambridge International A and AS Level components and some Cambridge O Level components.

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:

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- 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.

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- 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.

Question	Answer	Marks
1(a)(i)	work done per unit mass	**B1**
	idea of work done moving mass from infinity (to the point)	**B1**
1(a)(ii)	(gravitational) force is attractive	**B1**
	(gravitational) potential at infinity is zero	**B1**
	decrease in potential energy as masses approach *or* displacement and force in opposite directions	**B1**
1(b)(i)	*Either* $mv^2 / R = GMm / R^2$ *Or* $v = \sqrt{(GM / R)}$ $v^2 = (6.67 \times 10^{-11} \times 6.00 \times 10^{24}) / (7.30 \times 10^6)$	**C1**
	giving $v = 7.4 \times 10^3\ \text{m s}^{-1}$	**A1**
1(b)(ii)	$V_P = - GMm / R$	**C1**
	$= - (6.67 \times 10^{-11} \times 6.00 \times 10^{24} \times 340) / (7.30 \times 10^6)$	**C1**
	$V_P = - 1.9 \times 10^{10}$ J	**A1**
1(c)	$v^2 \propto 1 / r$, (r smaller) so v greater	**M1**
	and E_K greater	**A1**

Question	Answer	Marks
2(a)(i)	gas obeys formula pV / T = constant	**M1**
	symbols V and T explained	**A1**
2(a)(ii)	mean-square-speed (of atoms / molecules)	**B1**
2(b)(i)	use of $T = 393$	**C1**
	$pV = nRT$	**C1**
	$2.4 \times 10^5 \times 6.8 \times 10^{-3} = n \times 8.31 \times 393$ and $N = n \times 6.02 \times 10^{23} = 3.0 \times 10^{23}$	**A1**
	or $pV = NkT$	**(C1)**
	$2.4 \times 10^5 \times 6.8 \times 10^{-3} = N \times 1.38 \text{ x } 10^{-23} \times 393$ hence $N = 3.0 \times 10^{23}$	**(A1)**
2(b)(ii)	volume of one atom = $4 / 3\pi r^3$	**C1**
	volume occupied $= 3.0 \times 10^{23} \times 4 / 3 \times \pi \times (3.2 \times 10^{-11})^3$ $= 4 \times 10^{-8}\ \text{m}^3$	**A1**
2(b)(iii)	assumption: volume of atoms negligible compared to volume of container / cylinder	**B1**
	4×10^{-8} (m^3) << 6.8×10^{-3} (m^3) so yes	**B1**

Question	Answer	Marks
3(a)(i)	mention of upthrust and weight	**B1**
3(a)(ii)	upthrust is greater than the weight	**B1**
	(resultant force is) upwards	**B1**
3(b)	A, ρ, g *and* M are constant	**B1**
	either acceleration $\propto$ – displacement *or* acceleration $\propto$ displacement <u>and</u> (– sign indicates) a and x in opposite directions	**B1**
3(c)(i)	*either* $\omega = 2\pi / T$ *or* $\omega = 2\pi f$ <u>and</u> $f = 1 / T$	**C1**
	$\omega = 2\pi / 1.3$ $= 4.8\ \text{rad s}^{-1}$	**A1**
3(c)(ii)	$\omega^2 = A\rho g / m$	**C1**
	$4.83^2 = (4.5 \times 10^{-4} \times \rho \times 9.81) / 0.17$	**C1**
	$\rho = 900\ \text{kg m}^{-3}$	**A1**

Question	Answer	Marks
4(a)	Any three from: above the Equator period 24 hours orbits west to east one particular orbital radius	**B3**
4(b)	attenuation = 10 lg(P_1 / P_2) 194 = 10 lg (3.2 × 10^3 / P_2)	**C1**
	P_2 = 1.3 × 10^{-16} W	**A1**
4(c)	advantage: e.g. no tracking required	**B1**
	disadvantage: e.g. longer time delay	**B1**

Question	Answer	Marks
5(a)	region where charge experiences an (electric) force	**B1**
5(b)	graph: field strength zero from x = 0 to x = R	**B1**
	curve with negative gradient, decreasing from x = R to x = 3R	**B1**
	line passes through field strength E at x = R,	**B1**
	line passes through field strength 0.25E at x = 2R <u>and</u> field strength 0.11E at x = 3R	**B1**

Question	Answer	Marks
5(c)	field strength = $q / 4\pi\epsilon_0 x^2$	**C1**
	$2.0 \times 10^6 = q / (4 \times \pi \times 8.85 \times 10^{-12} \times 0.26^2)$	**C1**
	$q = 1.5 \times 10^{-5}$ C	**A1**

Question	Answer	Marks
6(a)	charge / potential (difference)	**M1**
	charge on one plate, p.d. between the plates	**A1**
6(b)(i)	all three capacitors connected in series	**B1**
6(b)(ii)	8 (μF) in parallel with the two 4 (μF) capacitors connected in series	**B1**
6(c)	discharge from 7.0 V to 4.0 V	**C1**
	Either energy = $\frac{1}{2}CV^2$ *or* energy = $\frac{1}{2} QV$ <u>and</u> $C = Q / V$	**C1**
	energy $= \frac{1}{2} \times 47 \times 10^{-6} \times (7^2 - 4^2)$ $= 7.8 \times 10^{-4}$ J	**A1**

Question	Answer	Marks
7(a)(i)	output voltage / input voltage	**B1**
7(a)(ii)	no time delay between input and output	**B1**
	clear reference to <u>change</u>(s) in input and / or output	**B1**
7(b)(i)	V_{IN} only connected to non-inverting input	**B1**
	midpoint between R_1 and R_2 only connected to inverting input	**B1**

Question	Answer	Marks
7(b)(ii)	gain = 1 + (R_1 / R_2) 25 = 1 + (12 × 10^3) / R_2	C1
	R_2 = 500 Ω	A1
7(b)(iii)	V_{MAX} = 9/25 = 0.36 V	C1
	range is –0.36 V to + 0.36 V	A1

Question	Answer	Marks
8(a)(i)	*Either* Newton's third law *or* equal and opposite forces	B1
	force on magnet is upwards	B1
	so force on wire downwards	B1
8(a)(ii)	using (Fleming's) left-hand rule	M1
	current from B to A	A1
8(b)	sinusoidal wave with at least 1 cycle	B1
	peaks at +6.4 mN and –6.4 mN	B1
	time period 25 ms	B1

Question	Answer	Marks
9	X-rays (are used)	**B1**
	(object is) scanned in sections / slices	**B1**
	either: scans taken at many angles / directions *or* images of each section / slice are 2-dimensional	**B1**
	scans of many sections / slices are combined	**B1**
	(to give) 3-dimensional image (of whole structure)	**B1**

Question	Answer	Marks
10(a)	single straight line along full length of solenoid	**B1**
	at least two more parallel lines along full length of solenoid	**B1**
	correct direction – right to left	**B1**
10(b)	(induced) e.m.f. proportional / equal to <u>rate</u>	**M1**
	of change of (magnetic) flux (linkage)	**A1**
10(c)	increasing current causes increasing flux	**B1**
	increasing flux induces e.m.f. in coil	**B1**
	(induced) e.m.f. opposes growth of current	**B1**

Question	Answer	Marks
11(a)	quantum / packet / discrete amount of <u>energy</u>	**M1**
	of electromagnetic radiation	**A1**
11(b)	$E = hc / \lambda$	**C1**
	$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (540 \times 10^{-9})$	**C1**
	$= (3.68 \times 10^{-19}) / (1.6 \times 10^{-19})$ $= 2.3$ eV	**A1**
11(c)	Any 4 from: photon absorbed by electron in valence band (1) photon energy > energy of forbidden band (1) electron promoted to conduction band (1) hole left in valence band (1) more charge carriers so lower resistance (1)	**B4**

Question	Answer	Marks
12(a)(i)	fission	**B1**
12(a)(ii)	*either* ${}^{0}_{-1}$e *or* ${}^{0}_{-1}\beta$	**M1**
	7	**A1**
12(b)(i)	energy $= c^2 \Delta m$ $= 0.223 \times 1.66 \times 10^{-27} \times (3.00 \times 10^{8})^2$	**C1**
	$= 3.33 \times 10^{-11}$ J	**A1**

Question	Answer	Marks
12(b)(ii)	Any 2 from: kinetic energy of products gamma photons neutrinos	B2

Cambridge International AS & A Level

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PHYSICS **9702/42**

Paper 4 A Level Structured Questions **March 2018**

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Maximum Mark: 100

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Question	Answer	Marks
1(a)(i)	*either* direction of force on a (small test) mass *or* direction of acceleration of a (small test) mass	**B1**
1(a)(ii)	Any three from: • the lines are radial • near the surface the lines are (approximately) parallel • parallel lines so constant field strength • constant field strength hence constant acceleration of free fall	**B3**
1(b)(i)	$g = GM / R^2$ $g = (6.67 \times 10^{-11} \times 7.35 \times 10^{22}) / (1.74 \times 10^3 \times 10^3)^2$	**C1**
	g = **1.62 N kg^{-1}**	**A1**
1(b)(ii)	*either* $x\omega^2 = GM / x^2$ <u>and</u> $\omega = 2\pi / T$ *or* $v^2 / x = GM / x^2$ <u>and</u> $v = 2\pi r / T$	**C1**
	$(1.74 \times 10^6 + 320 \times 10^3)^3 \times 4\pi^2 / T^2 = (6.67 \times 10^{-11} \times 7.35 \times 10^{22})$	**C1**
	$T^2 = 7.04 \times 10^7$ T = **8400 s** (8390)	**A1**

Question	Answer	Marks
2(a)	$pV = nRT$ $T = (5.60 \times 10^5 \times 3.80 \times 10^{-2}) / (5.12 \times 8.31)$	**C1**
	$T =$ **500 K**	**A1**
2(b)(i)	V / T is constant $V = (3.80 \times 10^4) \times (500 + 125) / 500$	**C1**
	$V =$ **4.75×10^4** cm^3	**A1**
2(b)(ii)	(for ideal gas,) change in internal energy is change in (total) kinetic energy (of molecules)	**B1**
	$\Delta U = 3 / 2 \times 1.38 \times 10^{-23} \times 125 \times 5.12 \times 6.02 \times 10^{23}$	**C1**
	= **7980** J	**A1**
2(c)(i)	$w = p\Delta V$ $= 5.60 \times 10^5 \times (4.75 - 3.80) \times 10^{-2}$	**C1**
	= **5320** J	**A1**
2(c)(ii)	total = 7980 + 5320 = **13300** J	**A1**

Question	Answer	Marks
3(a)	reasonably shaped circle or oval surrounding the origin	**B1**
	closed loop passing through $(0,\pm v_0)$ and $(\pm x_0,0)$	**B1**
3(b)	line from (0,0) to (90, F_0)	**B1**
	curve with decreasing positive gradient, zero gradient at $\theta = 90$	**B1**
3(c)	reasonable sinusoidal wave, one cycle, period 4.0 ms	**B1**
	amplitude at 4.0 V	**B1**
3(d)	U near right-hand end of line with Ba between U and peak of graph	**B1**
	Ba on right hand side of peak and Kr between Ba and peak of graph	**B1**

Question	Answer	Marks
4(a)	frequency at which body will vibrate when there is no (resultant external) resistive force acting on it OR frequency at which body will vibrate when there is no driving force / external force acting on it	**B1**
4(b)(i)	resonance	**B1**
4(b)(ii)	peak is not sharp / peak not infinite height	**M1**
	so damped	**A1**
4(c)	e.g. (quartz crystal) to produce ultrasound (quartz crystal) in watch to keep timing NMR / MRI microwave ovens tuning circuits	**B1**

Question	Answer	Marks
5(a)	<u>pulses</u> of ultrasound	**B1**
	reflected at boundaries (between media)	**B1**
	reflected pulses detected by (ultrasound) generator	**B1**
	Any three from:	
	(reflected signal) processed and displayed	**(B1)**
	time delay (between transmission and receipt) gives information about depth (of boundary)	**(B1)**
	intensity of reflected pulse gives information about (nature of) <u>boundary</u>	**(B1)**
	gel used to minimise reflection at skin / maximise transmission into skin	**(B1)**
	degree of reflection depends upon impedances of two media (at boundary)	**(B1)**
		B3
5(b)(i)	product of density and speed	**M1**
	of sound in the medium	**A1**
5(b)(ii)	(Z_1 about equal to Z_2,) coefficient very small / nearly 0	**B1**
	(Z_1 very different to Z_2,) coefficient nearly 1	**B1**

Question	Answer	Marks
6(a)(i)	0101	**A1**
6(a)(ii)	1000	**A1**
6(b)	sketch: series of steps	**B1**
	changes every 0.25 ms	**B1**
	correct heights 0, 5, 10, 12, 15, 8 at correct times Two marks for all levels correct One mark if one mistake	**B2**

Question	Answer	Marks
7(a)	work done per unit charge	**B1**
	(work done) moving positive charge from infinity (to the point)	**B1**
7(b)(i)	potential always same sign / potential is always positive so same sign of charge	**B1**

Question	Answer	Marks
7(b)(ii)	1 *from x = 12 cm to x = 25 cm:* speed increases and *from x = 27 cm to x = 31 cm*: speed decreases	**B1**
	(*from x = 12 cm to x = 25 cm:* speed increases) at decreasing rate or (*from x = 27 cm to x = 31 cm*: speed decreases) at increasing rate	**B1**
	at x = 26 cm: speed maximum	**B1**
	at 32 cm: speed still decreasing	**B1**
	2 $q\,\Delta V = ½mv^2$ $3.2 \times 10^{-19} \times (2.14 - 1.43) \times 10^4 = ½ \times 6.6 \times 10^{-27} \times v^2$ $v^2 = 6.88 \times 10^{11}$	**C1**
	v = **8.3** × **10⁵** m s⁻¹ (8.30)	**A1**

Question	Answer	Marks
8(a)(i)	all frequencies have the same gain	**B1**
8(a)(ii)	output changes at the same time as input changes	**B1**
8(b)(i)	R_T / 800 = 1.8 / 1.2 R_T = **1200** Ω	**A1**
8(b)(ii)	stepped from –9 V to +9 V or v.v.	**B1**
	V_{out} negative < R_T and V_{out} positive > R_T	**B1**
8(b)(iii)	correct LED symbol with connection between V_{OUT} and earth	**B1**
	diode pointing upwards	**B1**

Question	Answer	Marks
9(a)(i)	PSYV and QRXW	B1
9(a)(ii)	electron moving in magnetic field deflected towards face QRXW	M1
	so face PSYV is more positive	A1
9(b)(i)	PV *or* SY *or* RX *or* QW	B1
9(b)(ii)	number of charge carriers per unit volume	B1
9(b)(iii)	negative and positive charge (carriers) would deflect in opposite directions	M1
	so no change in polarity	A1

Question	Answer	Marks
10(a)(i)	*either* product of flux density and area	M1
	direction of flux normal to area	A1
	or flux density × area × sin θ	(M1)
	where θ is angle between direction of flux and area	(A1)
10(a)(ii)	(induced) e.m.f. proportional to rate	M1
	of change of (magnetic) flux linkage	A1
10(b)	e.m.f. $= \Delta(\phi N)/\Delta t$ $= (6.8 \times 10^{-6} \times 2 \times 3.5 \times 96) / (2.4 \times 10^{-3})$	C1
	= **1.9** V	A1

Question	Answer	Marks
10(c)	alternating	**C1**
	with same frequency as supply	**A1**

Question	Answer	Marks
11(a)	no forbidden band / valence and conduction bands overlap	**B1**
	no change in number of charge carriers (as temperature rises)	**B1**
	increased lattice vibrations so resistance increases	**B1**
11(b)	photons captured / absorbed by electrons in valence band	**B1**
	electrons promoted to conduction band	**B1**
	leaving holes in the valence band	**B1**
	more holes and / or electrons so resistance decreases	**B1**

Question	Answer	Marks
12(a)	Any 2 from: scattering of X-ray beam / no lead grid lack of collimation of beam / aperture large anode area large beam p.d. low / photon energy low / X-ray soft	**B2**
12(b)(i)	$0.81 = (e^{-1.5 \times 0.32}) / (e^{-1.5 \times x})$	**C1**
	x = **1.8** mm	**A1**

Question	Answer	Marks
12(b)(ii)	ratio/dB = 10 lg(0.81)	**C1**
	= (–) **0.92** dB	**A1**

Question	Answer	Marks
13(a)(i)	probability of decay (of a nucleus)	**M1**
	per unit time	**A1**
13(a)(ii)	$A = A_0\,e^{-\lambda t}$ after one half-life, $\frac{1}{2}A_0 = A_0\,e^{-\lambda t1/2}$	**M1**
	$\frac{1}{2} = \exp(-\lambda t_{½})$ and hence taking logs, $\ln 2 = \lambda t_{½}$	**A1**
13(b)	activity $= 3.8 \times 10^4 \exp(-\ln 2 \times 36 / 15)$	**C1**
	= 7200 Bq	**C1**
	or activity $= 3.8 \times 10^4 / 2^{2.4}$	**(C1)**
	= 7200 Bq	**(C1)**
	volume $= (7200 / 1.2) \times 5.0$	**C1**
	$= 3.0 \times 10^4\ \text{cm}^3$	**A1**
	OR activity of $5.0\ \text{cm}^3$ $= 1.2 \times 2^{2.4}$	**(C1)**
	= 6.3336 Bq	**(C1)**
	volume $= (3.8 \times 10^4 / 6.3336) \times 5.0$	**(C1)**
	$= 3.0 \times 10^4\ \text{cm}^3$	**(A1)**

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **October/November 2018**

MARK SCHEME

Maximum Mark: 100

Published

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Question	Answer	Marks
1(a)(i)	work done per unit mass	**B1**
	work done moving mass from infinity (to the point)	**B1**
1(a)(ii)	(near Earth's surface change in) height $\ll$ radius **or** height <u>much</u> less than radius	**B1**
	potential inversely proportional to radius **and** radius approximately constant (so potential approximately constant)	**B1**
1(b)	initial kinetic energy = (–) potential energy (at surface) **or** $\frac{1}{2}mv^2 = GMm/r$	**B1**
	$v^2 = (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22})/(0.5 \times 3.5 \times 10^6)$	**C1**
	$v = 2.4 \times 10^3\,\mathrm{m\,s^{-1}}$	**A1**

Question	Answer	Marks
2(a)	sum of potential and kinetic energies (of molecules/atoms/particles)	**B1**
	(energy of) molecules/atoms/particles in random motion	**B1**
2(b)(i)	final temperature = initial temperature	**B1**
	no change in internal energy	**B1**
2(b)(ii)	**1.** work done on gas (P$\rightarrow$Q): 0	**A1**
	increase in internal energy (P$\rightarrow$Q): (+)97.0 J	**A1**
	2. increase in internal energy (Q$\rightarrow$R): –42.5 J	**A1**
	3. increase in internal energy (R$\rightarrow$P): –54.5 J	**A1**
	thermal energy supplied (R$\rightarrow$P): –91.5 J	**A1**

Question	Answer	Marks
3(a)	$\omega^2 = 2g / L$	**C1**
	$T = 2\pi / \omega$	**C1**
	$\omega^2 = (2 \times 9.81) / 0.19$ $\omega = 10.2$ (rad s^{-1}) $T = 2\pi / 10.2$ $= 0.62$ s	**A1**
3(b)(i)	e.g. viscosity of liquid/friction within the liquid/viscous drag/friction between walls of tube and liquid	**B1**
3(b)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2 x_0^2$	**C1**
	change = $\frac{1}{2} \times 18 \times 10^{-3} \times 103 \times [(2.0 \times 10^{-2})^2 - (0.95 \times 10^{-2})^2]$	**C1**
	$= 2.9 \times 10^{-4}$ J	**A1**

Question	Answer	Marks
4(a)	pulses (of ultrasound from generator)	**B1**
	reflected at boundaries (between media)	**B1**
	time delay (between transmission and receipt) gives information about depth	**B1**
	intensity of reflected pulse gives information about nature (of tissues)/type (of tissues)/boundary	**B1**
	Any two from: • (reflected pulses) detected by the (ultrasound) generator • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	**B2**
4(b)(i)	product of density and speed	**M1**
	speed of ultrasound in medium	**A1**
4(b)(ii)	Z_1 about equal to Z_2 results in negligible/no reflection	**B1**
	$Z_1 \gg Z_2$ (or $Z_1 \ll Z_2$) results in mostly reflection	**B1**

Question	Answer	Marks
5(a)	Any two reasonable suggestions e.g.: • noise can be eliminated/(signal/data) can be regenerated • bits can be added to correct for errors • data compression/multiplexing (is possible) • signal can be encrypted/better security	**B2**
5(b)	sketch: series of seven steps	**B1**
	each step width 2 ms	**B1**
	correct levels in correct order (2, 5, 14, 4, 9, 11, 7) (*1 mark for 6 levels correct, 2 marks for 7 levels correct*)	**A2**
5(c)(i)	step width reduced **or** higher frequencies can be reproduced	**B1**
5(c)(ii)	step height reduced **or** smaller <u>changes</u> in signal (intensity) can be reproduced	**B1**

Question	Answer	Marks
6(a)(i)	work done per unit charge	**B1**
	work done moving positive charge from infinity (to the point)	**B1**
6(a)(ii)	field strength = potential gradient	**M1**
	'–' sign included **or** directions discussed	**A1**
6(b)(i)	gain in kinetic energy (= loss in potential energy) = charge × p.d. **or** $qV = ½mv^2$	**M1**
	so v is independent of separation (because separation not in expressions)	**A1**

Question	Answer	Marks
6(b)(ii)	(at x = 0.40 cm), potential = (–) 75 × 0.40 / 1.2 (= (–) 25 V)	C1
	$\frac{1}{2}mv^2 = qV$ $\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 25$	C1
	or	
	$a = Vq/dm$ **and** $v^2 = 2as$	**(C1)**
	$v^2 = (2 \times 75 \times 2 \times 1.60 \times 10^{-19} \times 0.40 \times 10^{-2}) / (1.2 \times 10^{-2} \times 4 \times 1.66 \times 10^{-27})$	**(C1)**
	$v = 4.9 \times 10^4\,\text{m s}^{-1}$	A1

Question	Answer	Marks
7(a)(i)	gain is constant	M1
	for all frequencies	A1
7(a)(ii)	no time delay between input (voltage) and output (voltage)	B1
	clear reference to <u>change</u>(s) in input and/or output (voltages)	B1
7(b)	diagram: V_{IN} connected to V^+ only	B1
	midpoint between resistors R_1 and R_2 connected to V^- only	B1
7(c)(i)	–3.6 V	A1
7(c)(ii)	(+)5.0 V	A1

Question	Answer	Marks
8(a)	region where there is a force	**M1**
	experienced by a current-carrying conductor/moving charge/(permanent) magnet	**A1**
8(b)(i)	single path, deflection in 'upward' direction	**B1**
	acceptable circular arc in whole field	**B1**
	no 'kinks' at start or end of curvature, and straight outside region of field	**B1**
8(b)(ii)	force (on particle) is normal to velocity/direction of motion/direction of speed	**B1**
8(c)	magnetic force provides/is the centripetal force	**B1**
	$Bqv = mv^2 / r$ **or** $r = mv / Bq$	**C1**
	(if q is doubled), new speed = $2v$	**A1**

Question	Answer	Marks
9(a)	(induced) e.m.f. proportional/equal to <u>rate</u>	**M1**
	of change of (magnetic) flux (linkage)	**A1**
9(b)(i)	induced e.m.f. $= (\Delta B)AN / \Delta t$ $= (2 \times 0.19 \times 1.5 \times 10^{-4} \times 120) / 0.13$	**C1**
	$= 0.053\,\text{V}$	**A1**
9(b)(ii)	reading on voltmeter connected to coil C / V: 0 0.053 0 (*all three values required*)	**A1**
	reading on voltmeter connected to Hall probe / V: zero in middle column	**B1**
	final column correct sign (negative)	**B1**
	final column correct magnitude (0.20)	**B1**

Question	Answer	Marks
10	Any five points from: • as temperature rises electrons gain energy • electrons enter conduction band • (positively charged) holes left in valence band • more charge carriers (so resistance decreases) • (as temperature rises,) lattice vibrations increase • effect of increase in number of electrons or holes or charge carriers outweighs effect of increased lattice vibrations (so resistance decreases)	**B5**

Question	Answer	Marks
11(a)	discrete amount/quantum/packet of <u>energy</u>	**M1**
	of electromagnetic radiation	**A1**
11(b)(i)	energy = hc/λ	**C1**
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8})/(0.51 \times 10^{6} \times 1.60 \times 10^{-19})$ $= 2.4 \times 10^{-12}\,\text{m}$	**A1**
11(b)(ii)	$p = h/\lambda$ $= (6.63 \times 10^{-34})/(2.44 \times 10^{-12})$ **or** $p = E/c$ $= (0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^{8})$	**C1**
	$p = 2.7 \times 10^{-22}\,\text{N s}$	**A1**
11(c)(i)	$E = c^2\Delta m$	**C1**
	$\Delta m = (0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^{8})^2$ $= 9.1 \times 10^{-31}\,\text{kg}$	**A1**
11(c)(ii)	(momentum is conserved so) nucleus must have momentum in opposite direction to photon	**B1**

Question	Answer	Marks
12(a)	unstable nucleus	**B1**
	emission of particles/photons	**B1**
	emission is spontaneous **or** (particles/radiation) are ionising	**B1**
12(b)(i)	tangent drawn and gradient calculation attempted	**B1**
	activity = 1.3×10^6 Bq (*1 mark for answer within* ±0.2×10^6 Bq, *2 marks for answer within* ±0.1×10^6 Bq)	**A2**
12(b)(ii)	$A = \lambda N$	**C1**
	$\lambda = (1.3 \times 10^6) / (3.05 \times 10^{10}) = 4.3 \times 10^{-5}\,\text{s}^{-1}$ ($\approx 4 \times 10^{-5}\,\text{s}^{-1}$)	**A1**
12(c)	$A = A_0 e^{-\lambda t}$ $1.0 \times 10^3 = 4.6 \times 10^3 \exp(-5.5 \times 10^{-7} \times t)$	**C1**
	$\ln(4.6) = 5.5 \times 10^{-7} \times t$	**C1**
	$t = 2.78 \times 10^6$ s = 32 days	**A1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS **9702/41**

Paper 4 A Level Structured Questions **October/November 2019**

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Question	Answer	Marks
1(a)	force proportional to product of masses and inversely proportional to square of separation	**B1**
	idea of (gravitational) force between point masses	**B1**
1(b)(i)	above the equator	**B1**
	from west to east	**B1**
1(b)(ii)	gravitational force provides/is the centripetal force	**B1**
	$GM / r^2 = r(2\pi / T)^2$	**C1**
	$(6.67 \times 10^{-11} \times M) = \{(4.23 \times 10^7)^3 \times 4\pi^2\} / (24 \times 3600)^2$	**C1**
	$M = 6.0 \times 10^{24}$ kg	**A1**

Question	Answer	Marks
2(a)	(total volume of molecules is) negligible	**M1**
	compared with volume occupied by the gas	**A1**
2(b)(i)	$pV = NkT$	**C1**
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = N \times 1.38 \times 10^{-23} \times (273 + 23)$	**C1**
	or	
	$pV = nRT$	**(C1)**
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (273 + 23)$ $n = 4.49$ (mol) $N = nN_A$ $= 4.49 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.7 \times 10^{24}$	**A1**

Question	Answer	Marks
2(b)(ii)	volume of one atom $= d^3$ ($= 2.7 \times 10^{-29}$ m^3)	**C1**
	volume of all atoms $= 2.7 \times 10^{-29} \times 2.7 \times 10^{24}$	**C1**
	$= 7 \times 10^{-5}$ m^3	**A1**
	or	
	volume of one atom $= (4 / 3)\pi r^3$ ($= 1.41 \times 10^{-29}$ m^3)	**(C1)**
	volume of all atoms $= 2.7 \times 10^{24} \times 1.41 \times 10^{-29}$	**(C1)**
	$= 4 \times 10^{-5}$ m^3	**(A1)**
2(c)	numerical comparison between answer to **(b)(ii)** and 2.4×10^{-2} (m^3) showing **(b)(ii)** is <u>much</u> less than 2.4×10^{-2} (m^3)	**B1**

Question	Answer	Marks
3(a)	(thermal) energy per (unit) mass (to change state)	**B1**
	(heat transfer during) change of state at constant temperature	**B1**
3(b)(i)	32 g	**A1**
3(b)(ii)	temperature difference (between liquid and surroundings) does not change	**B1**
3(b)(iii)	$VIt = mL$	**C1**
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$ **or** $190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	**C1**
	$86 \times 600 = (56 - 32) \times L$	**C1**
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	**(C1)**
	$276 - 190 = (24 \times L) / 600$	**(C1)**
	$L = 2200\ \text{J g}^{-1}$	**A1**

Question	Answer	Marks
3(b)(iv)	$230 \times 1.2 \times 600 = (56 \times 2150) + H$ **or** $190 \times 1.0 \times 600 = (32 \times 2150) + H$	**C1**
	$H = 45\,200$ rate $= 45\,200 / 600$ $= 75$ W	**A1**
	or	
	$230 \times 1.2 = (56 \times 2150) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times 2150) / (60 \times 10) + P$	**(C1)**
	rate (= P) = 75 W	**(A1)**

Question	Answer	Marks
4(a)(i)	distance from a (reference) point in a given direction	**B1**
4(a)(ii)	line is not straight **or** gradient is not constant	**B1**
4(b)(i)	0.85–0.90 cm	**A1**
4(b)(ii)	$a = -(2\pi f)^2 x$	**C1**
	e.g. $1.2 = 4\pi^2 \times f^2 \times (0.90 \times 10^{-2})$	**C1**
	$f = 1.8$ Hz	**A1**
4(c)	complete circle/ellipse enclosing the origin	**B1**
	closed shape passing through $(0, \pm v_0)$ and $(\pm x_0, 0)$	**B1**

Question	Answer	Marks
5(a)(i)	provides return for the signal	B1
	shields signal from noise	B1
5(a)(ii)	e.g. connection between aerial and TV set	B1
5(b)(i)	gain / dB = 10 lg (P_1 / P_2)	C1
	32 = 10 lg {P_{MIN} / (7.6 × 10^{-6})} P_{MIN} = 0.012 W	A1
5(b)(ii)	attenuation per unit length = (1 / L) × 10 lg (P_1 / P_2) 6.3 = (1 / L) × 10 lg (2.6 / 0.012)	C1
	L = 3.7 km	A1

Question	Answer	Marks
6(a)	(E =) $Q / 4\pi\varepsilon_0 r^2$	**M1**
	where ε_0 is permittivity (of free space)	**A1**
6(b)(i)	field does not change direction/field does not become zero	**M1**
	so (charges have) opposite (sign)	**A1**
6(b)(ii)	minimum is at the midpoint (between the charges)	**M1**
	so (magnitudes are the) same	**A1**
6(c)	force = field strength × charge **and** force = mass × acceleration **or** acceleration is proportional to field strength	**B1**
	(from x = 3.0 cm) to x = 5.0 cm: acceleration decreases	**B1**
	at x = 5.0 cm: acceleration is a minimum	**B1**
	from x = 5.0 cm (to x = 7.0 cm): acceleration increases	**B1**

Question	Answer	Marks
7(a)(i)	all frequencies are amplified equally	**B1**
7(a)(ii)	no drop in output voltage (when there is a current)	**B1**
7(b)(i)	gain = 1 + R_F / R_{IN} = 1 + (4000 / 800)	**C1**
	= 6.0	**A1**
7(b)(ii)	2.0 / V_{IN} = 6.0 V_{IN} = (+)0.33 V	**A1**
7(b)(iii)	5.0 V	**A1**
7(b)(iv)	V = 5.0 – 2.2 (= 2.8 V)	**C1**
	R = V / I = 2.8 / 0.020 = 140 Ω	**A1**

Question	Answer	Marks
8(a)	concentric circles (around the wire)	**M1**
	at least 3 circles shown, all with increasing separation	**A1**
	direction anticlockwise	**B1**
8(b)(i)	$B = (4\pi \times 10^{-7} \times 6.2) / (2\pi \times 3.1 \times 10^{-2})$	**C1**
	$= 4.0 \times 10^{-5}$ T	**A1**
8(b)(ii)	$F = BIL$ **or** $F / L = BI$	**C1**
	$F / L = 4.0 \times 10^{-5} \times 8.5$ $= 3.4 \times 10^{-4}$ N m^{-1}	**A1**
8(c)	correct application of Newton's 3rd law to the forces **or** F / L is proportional to the product of the two currents	**M1**
	so same magnitude	**A1**

Question	Answer	Marks
9(a)	nuclei precess	**B1**
	precession is about (direction of magnetic) field **or** frequency of precession is in radio-frequency range	**B1**
9(b)	• frequency (of precession) depends on field strength • to locate/find position of (spinning) nuclei • to change region where nuclei are detected *any two points, one mark each*	**B2**

Question	Answer	Marks
10(a)(i)	lower right **and** upper left diodes circled	**B1**
10(a)(ii)	maximum = 7.0√2 = 9.9 V	**A1**
10(b)(i)	correct symbol for capacitor, shown connected in parallel with R	**B1**
10(b)(ii)	**1.** (ripple) decreases	**B1**
	2. (ripple) increases	**B1**

Question	Answer	Marks
11(a)	energy (of photon) required to remove electron	**M1**
	from a surface **or** reference to <u>minimum</u> energy **or** reference to zero <u>kinetic</u> energy	**A1**
11(b)(i)	**1.** photon energy $= hc / \lambda$	**C1**
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (280 \times 10^{-9})$ $= 7.1 \times 10^{-19}$ J	**A1**
	2. electron energy $= (7.1 - 5.5) \times 10^{-19}$ J	**C1**
	$½ \times 9.11 \times 10^{-31} \times v^{2} = (7.1 - 5.5) \times 10^{-19}$	**C1**
	$v = 5.9 \times 10^{5}$ m s^{-1}	**A1**
11(b)(ii)	energy is required to bring electron to the surface	**B1**
11(c)	no change / decreases increases / decreases	**B4**

Question	Answer	Marks
12(a)	$E = (3.0 \times 10^8)^2 \times 1.66 \times 10^{-27}$ (= 1.49×10^{-10} J)	**M1**
	= $(1.49 \times 10^{-10}) / (1.60 \times 10^{-19}) = 9.34 \times 10^8$ = 934 MeV	**A1**
	or	
	binding energy = 8.443×95 [or equivalent using La-139 nucleus]	**(M1)**
	binding energy / mass defect = $(8.443 \times 95) / 0.859$ = 934 MeV	**(A1)**
12(b)(i)	binding energy = 1.865×934 (= 1741.91 MeV)	**C1**
	binding energy per nucleon = 1741.91 / 235 = 7.41 (MeV)	**A1**
12(b)(ii)	less (than)	**B1**
12(c)	energy = $\{(1.219 + 0.859) - 1.865)\} \times 934$ **or** energy = $(95 \times 8.443) + (139 \times 8.189) - (235 \times 7.412)$	**C1**
	= 199 MeV	**A1**
12(d)	number of reactions = $1.2 \times 10^{-7} \times 6.02 \times 10^{23}$ = 7.22×10^{16}	**C1**
	energy release (for one reaction) = $199 \times 1.60 \times 10^{-13}$ (= 3.18×10^{-11} J)	**C1**
	power = $(7.22 \times 10^{16} \times 3.18 \times 10^{-11}) / (25 \times 10^{-3})$ = 9.2×10^7 W	**A1**

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.

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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.

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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	<u>'List rule' guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

Abbreviations

/	Alternative and acceptable answers for the same marking point.
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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.
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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. Within 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.
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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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Question	Answer	Marks
1(a)	force per unit mass	**B1**
1(b)	$GMm / r^2 = mr\omega^2$ **and** $\omega = 2\pi/T$ **or** $GMm / r^2 = mv^2 / r$ **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 6.0×10^{24}	**(C1)**
	$6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (150 \times 60)]^2$ so $r = 9.4 \times 10^6$ m	**(A1)**
1(c)(ii)	separation increases so (potential energy) increases **or** 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 **or** mean square speed (directly) proportional to kinetic energy (of molecules) **or** 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 **or** 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 **or** 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 $= (3.0 \times 10^8) / (300 \times 10^3)$ $= 1000$ 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**
	$73 = 10 \lg (P_T / P_R)$ $73 = 10 \lg (P_T\, x^2 / 0.082\, P_T)$ **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 ($2r$, $E_0 / 4$) and ($3r$, $E_0 / 9$)	**B1**
6(b)	from $p = p_0 / 2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	**B1**
	line passing through (½p_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, ½N_0)	**B1**
	line passing through (30, $0.75N_0$) <u>and</u> (45, $0.88N_0$)	**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 **or** 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 **or** $V^- > V^+$	**B1**
	output is negative so (LED) does not emit light	**B1**
8(c)	at 0 °C, $V^- = 1.7$ V **or** 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**
	$2.5 / 3.0 = 1.8 / R$ **or** $[R / (R + 1.8)] \times 3.0 = 1.6$	**C1**
	$R = 2.2$ kΩ	**A1**

Question	Answer	Marks
9(a)	region where there is a force exerted on	**M1**
	a current-carrying conductor **or** a <u>moving</u> charge **or** 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) **or** 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
	$I_S = I_0 \exp(-0.92 \times 9.0)$ $= 2.5 \times 10^{-4}\ I_0$	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)** e.g. $I_S \gg I_C$ so good contrast	B1

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

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS	**9702/41**
Paper 4 A Level Structured Questions	**May/June 2020**
MARK SCHEME	
Maximum Mark: 100	

Published

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Question	Answer	Marks
1(a)	force acting between two masses **or** force on mass due to another mass **or** force on mass in a gravitational field	B1
1(b)	arc length = $r\theta$ $d = 1.5 \times 10^{17} \times 1.2 \times 10^{-5} = 1.8 \times 10^{12}$ m	A1
1(c)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (44.2 \times 365 \times 24 \times 3600)$ $= 4.5 \times 10^{-9}$ rad s^{-1}	A1
1(c)(ii)	gravitational forces are equal **or** centripetal force about P is the same	C1
	$M_1 x\omega^2 = M_2(d - x)\omega^2$ so $M_1 / M_2 = (d - x) / x$	A1
1(c)(iii)	$x = 0.4d$	C1
	$6.67 \times 10^{-11} \times M_1 = (1.0 - 0.4) \times (1.8 \times 10^{12})^3 \times (4.5 \times 10^{-9})^2$	C1
	$M_1 = 1.1 \times 10^{30}$ kg	A1

Question	Answer	Marks
2(a)	total potential energy and kinetic energy (of molecules/atoms)	**M1**
	reference to random motion of molecules/atoms	**A1**
2(b)	(in ideal gas,) no intermolecular forces	**B1**
	no potential energy (so change in kinetic energy is change in internal energy)	**B1**
2(c)	(random) potential energy of molecules does not change	**M1**
	(random) kinetic energy of molecules does not change	**M1**
	so internal energy does not change	**A1**
	or	
	decrease in total potential energy = gain in total kinetic energy	**(M1)**
	no external energy supplied	**(M1)**
	so internal energy does not change	**(A1)**
	or	
	no compression (of ball) so no work done on the ball	**(M1)**
	no resistive forces so no heating of the ball	**(M1)**
	so internal energy does not change	**(A1)**

Question	Answer	Marks
2(c)	**or**	
	no change of state so potential energy (of molecules) unchanged	**(M1)**
	no temperature rise so kinetic energy (of molecules) unchanged	**(M1)**
	so internal energy does not change	**(A1)**

Question	Answer	Marks
3(a)(i)	amplitude = 4.9 cm	**A1**
3(a)(ii)	frequency = 2700 / 60 = 45 Hz	**A1**
3(a)(iii)	$v_0 = x_0\omega$ **and** $\omega = 2\pi f$	**C1**
	$v_0 = 4.9 \times 10^{-2} \times 2\pi \times 45$ $= 14\ \text{m s}^{-1}$	**A1**
3(a)(iv)	$v = \omega(x_0^2 - x^2)^{½}$ $= 2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{½}$	**C1**
	$= 12\ \text{m s}^{-1}$	**A1**

Question	Answer	Marks
3(b)	$F = ma$ **and** $a_0 = v_0\omega$ **or** $a_0 = x_0\omega^2$	C1
	$F = 0.64 \times 13.9 \times 2\pi \times 45$ **or** $0.64 \times 4.9 \times (2\pi \times 45)^2$	C1
	= 2500 N	A1

Question	Answer	Marks
4(a)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
4(a)(ii)	the greater the difference between Z_1 and Z_2, the closer the ratio is to 1 **or** if difference between Z_1 and Z_2 large, ratio is close to 1	B1
	the closer together Z_1 and Z_2, the closer the ratio is to 0 **or** if difference between Z_1 and Z_2 small, ratio close to 0	B1
4(b)(i)	loss of intensity/amplitude/power (of the wave)	B1
4(b)(ii)	$I = I_0 e^{-\mu x}$	C1
	$0.35 = e^{-0.046\mu}$ $\mu = 23\ m^{-1}$	A1

Question	Answer	Marks
5(a)	similarity: both are radial **or** both have inverse square (variations)	**B1**
	difference: direction is always/only towards the mass **or** direction can be towards or away from charge	**B1**
5(b)	field strength = $Q / 4\pi\varepsilon_0 x^2$	**C1**
	$E = Q / 36\pi\varepsilon_0 R^2$	**A1**
5(c)(i)	fields (due to each sphere) are in same direction	**B1**
5(c)(ii)	charges on spheres attract/affect each other **or** charge distribution on each sphere distorted by the other sphere **or** charges on the surface of the spheres move	**B1**
	spheres are not point charges (at their centres)	**B1**

Question	Answer	Marks
6(a)(i)	greater information carrying capacity	B1
6(a)(ii)	power/energy is radiated	B1
	signal picked up by adjacent fibre/wire	B1
6(b)	ratio / dB = 10 lg(P_2 / P_1)	C1
	13 = 10 lg [P / (1.0 × 10^{-3})] and so P = 20 mW	A1
6(c)	45 × 0.18 = 10 lg (20 / P)	C1
	P = 3.1 mW	A1

Question	Answer	Marks
7(a)	output signal proportional to input signal	**B1**
	output signal has same sign/polarity as input signal	**B1**
7(b)(i)	gain $= V_{OUT} / V_{IN}$ $= 2.6 / 0.084$ $= 31$	**A1**
7(b)(ii)	$31 = 1 + (15 \times 10^3) / R$	**C1**
	$R = 500\ \Omega$	**A1**
7(c)(i)	e.g. cathode-ray oscilloscope/CRO	**B1**
7(c)(ii)	gain is reduced	**B1**
	(so) V_{OUT} is smaller	**B1**

Question	Answer	Marks
8(a)	magnetic field normal to current	**B1**
	newton per ampere	**B1**
	newton per metre	**B1**
8(b)(i)	current in wire QL gives rise to a force **or** wire QL is perpendicular to the magnetic field	**B1**
	force on wire QL is vertical	**B1**
	force does not act through the pivot	**B1**
8(b)(ii)	forces act through the same line **or** forces are horizontal	**B1**
	forces are equal (in magnitude) and opposite (in direction)	**B1**
8(c)(i)	change $= mg \times (\Delta)L$	**C1**
	$= 1.3 \times 10^{-4} \times 9.81 \times 2.6 \times 10^{-2} = 3.3 \times 10^{-5}$ N m^{-1}	**A1**
8(c)(ii)	change = $B \times (\Delta)I \times L \times x$	**C1**
	$3.3 \times 10^{-5} = B \times 1.2 \times 0.85 \times 10^{-2} \times 5.6 \times 10^{-2}$	**C1**
	$B = 0.058$ T	**A1**

Question	Answer	Marks
9(a)(i)	e.m.f. = $(\Delta)B \times AN / t$	C1
	= $45 \times 10^{-3} \times \pi \times (1.8 \times 10^{-2})^2 \times 350 / 0.20 = 0.080$ V	A1
9(a)(ii)	0 to 0.2 s: straight horizontal line at 0.080 V or –0.080 V	B1
	0.2 s to 0.4 s: zero	B1
	0.4 s to 0.8 s: straight horizontal line at 0.040 V or –0.040 V	B1
	opposite polarity to 0 to 0.2 s line	B1
9(b)	either disc cuts flux lines (of the magnet) **or** there is a changing flux in the disc	B1
	(by Faraday's law) e.m.f. is induced in the disc	B1
	e.m.f. causes (eddy) currents in the disc	B1
	current in the magnetic field (of the magnet) causes force on disc	B1

Question	Answer	Marks
10(a)	• photon gives energy to electron (in an inner shell) **or** electron (in an inner shell) absorbs a photon • electron moves (from lower) to higher energy level • energy (of photon) is equal to difference in energy levels • electron de-excites giving off photon (of same energy) • photons emitted in all directions *Any four points, 1 mark each*	**B4**
10(b)	(in light) photons gives energy to electrons in VB **or** (in light) electrons in VB absorb photons	**B1**
	electron crosses FB/jumps to CB	**B1**
	(positive) holes left/created in VB	**B1**
	low intensity: few electrons in CB/most electrons in VB **or** high intensity: more photons so more electrons in CB **or** electron-hole pairs are charge carriers	**B1**
	more charge carriers results in lower resistance	**B1**

Question	Answer	Marks
11(a)(i)	$E = mc^2$	C1
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$ $= 8.2 \times 10^{-14}$ J	A1
11(a)(ii)	$p = h / \lambda$ **and** $E = hc / \lambda$ **or** $E = pc$	C1
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$ $= 2.7 \times 10^{-22}$ N s	A1
11(b)	total momentum (before and after interaction) is zero **or** momentum must be conserved (in the interaction) **or** momentum of the photons must be equal and opposite	B1
	(photons emitted in) opposite directions	B1

Question	Answer	Marks
12(a)(i)	time at which a nucleus will decay cannot be predicted **or** constant probability of decay of a nucleus	**B1**
12(a)(ii)	decay (of a nucleus) not affected by environmental factors	**B1**
12(b)	$A = A_0 e^{-\lambda t}$ **and** $\lambda = \ln 2 / t_{½}$	**C1**
	$= 3.6 \times 10^5 \times \exp[-(2 \times \ln 2) / 1.4]$	**C1**
	or	
	$A = A_0 \times 0.5^N$	**(C1)**
	$= 3.6 \times 10^5 \times 0.5^N$ where $N = 2 / 1.4$	**(C1)**
	$A = 1.3 \times 10^5$ Bq	**A1**
12(c)(i)	smooth curve, starting at (0, 3.6×10^5) and passing through (1.4, 1.8×10^5) and (2.0, 1.3×10^5)	**B1**
12(c)(ii)	(activity of sample is greater than activity of X so) there must be an additional source of activity	**C1**
	the decay product (of isotope X) is radioactive	**A1**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/43**

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.

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	<u>'List rule' guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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. Within 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)	force per unit mass	**B1**
1(b)	$GMm / r^2 = mr\omega^2$ **and** $\omega = 2\pi/T$ **or** $GMm / r^2 = mv^2 / r$ **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 6.0×10^{24}	**(C1)**
	$6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (150 \times 60)]^2$ so $r = 9.4 \times 10^6$ m	**(A1)**
1(c)(ii)	separation increases so (potential energy) increases **or** 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 **or** mean square speed (directly) proportional to kinetic energy (of molecules) **or** 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 **or** 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 **or** 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 $= (3.0 \times 10^8) / (300 \times 10^3)$ $= 1000$ 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**
	$73 = 10 \lg (P_T / P_R)$ $73 = 10 \lg (P_T x^2 / 0.082 P_T)$ **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 $(2r, E_0 / 4)$ and $(3r, E_0 / 9)$	**B1**
6(b)	from $p = p_0 / 2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	**B1**
	line passing through $(\frac{1}{2}p_0, 2\lambda_0)$	**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 $(15, \frac{1}{2}N_0)$	**B1**
	line passing through $(30, 0.75N_0)$ <u>and</u> $(45, 0.88N_0)$	**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 and 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 **or** 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 **or** $V^- > V^+$	**B1**
	output is negative so (LED) does not emit light	**B1**
8(c)	at 0 °C, $V^- = 1.7$ V **or** 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**
	$2.5 / 3.0 = 1.8 / R$ **or** $[R / (R + 1.8)] \times 3.0 = 1.6$	**C1**
	$R = 2.2$ kΩ	**A1**

Question	Answer	Marks
9(a)	region where there is a force exerted on	**M1**
	a current-carrying conductor **or** a <u>moving</u> charge **or** 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 change 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) **or** smaller rate 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**
	$I_S = I_0 \exp(-0.92 \times 9.0)$ $= 2.5 \times 10^{-4}\ I_0$	**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)** e.g. $I_S \gg I_C$ so good contrast	**B1**

Question	Answer	Marks
12(a)	• frequency determines energy of photon • intensity determines number of photons (per unit time) • intensity does not determine energy of a photon *Any two points, 1 mark each*	**B2**
	kinetic energy (of the electron) depends on the energy of one photon	**B1**
12(b)(i)	$E = hc / \lambda$ **or** $E = hf$ **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) = 5.0 eV	**A1**
12(b)(ii)	E_{MAX} = photon energy – work function	**C1**
	work function = 5.0 – 1.4 = 3.6 eV	**A1**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS	**9702/43**
Paper 4 A Level Structured Questions	**May/June 2020**
MARK SCHEME	
Maximum Mark: 100	

Published

Students did not sit exam papers in the June 2020 series due to the Covid-19 global pandemic.

This mark scheme is published to support teachers and students and should be read together with the question paper. It shows the requirements of the exam. The answer column of the mark scheme shows the proposed basis on which Examiners would award marks for this exam. Where appropriate, this column also provides the most likely acceptable alternative responses expected from students. Examiners usually review the mark scheme after they have seen student responses and update the mark scheme if appropriate. In the June series, Examiners were unable to consider the acceptability of alternative responses, as there were no student responses to consider.

Mark schemes should usually be read together with the Principal Examiner Report for Teachers. However, because students did not sit exam papers, there is no Principal Examiner Report for Teachers for the June 2020 series.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the June 2020 series for most Cambridge IGCSE™ and Cambridge International A & AS Level components, and some Cambridge O Level components.

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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	<u>‘List rule’ guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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. Within 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)	force acting between two masses **or** force on mass due to another mass **or** force on mass in a gravitational field	B1
1(b)	arc length = $r\theta$ $d = 1.5 \times 10^{17} \times 1.2 \times 10^{-5} = 1.8 \times 10^{12}$ m	A1
1(c)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (44.2 \times 365 \times 24 \times 3600)$ $= 4.5 \times 10^{-9}$ rad s^{-1}	A1
1(c)(ii)	gravitational forces are equal **or** centripetal force about P is the same	C1
	$M_1 x\omega^2 = M_2(d - x)\omega^2$ so $M_1 / M_2 = (d - x) / x$	A1
1(c)(iii)	$x = 0.4d$	C1
	$6.67 \times 10^{-11} \times M_1 = (1.0 - 0.4) \times (1.8 \times 10^{12})^3 \times (4.5 \times 10^{-9})^2$	C1
	$M_1 = 1.1 \times 10^{30}$ kg	A1

Question	Answer	Marks
2(a)	total potential energy and kinetic energy (of molecules/atoms)	**M1**
	reference to <u>random</u> motion of molecules/atoms	**A1**
2(b)	(in ideal gas,) no intermolecular forces	**B1**
	no potential energy (so change in kinetic energy is change in internal energy)	**B1**
2(c)	(random) potential energy of molecules does not change	**M1**
	(random) kinetic energy of molecules does not change	**M1**
	so internal energy does not change	**A1**
	or	
	decrease in total potential energy = gain in total kinetic energy	**(M1)**
	no external energy supplied	**(M1)**
	so internal energy does not change	**(A1)**
	or	
	no compression (of ball) so no work done on the ball	**(M1)**
	no resistive forces so no heating of the ball	**(M1)**
	so internal energy does not change	**(A1)**

Question	Answer	Marks
2(c)	**or**	
	no change of state so potential energy (of molecules) unchanged	**(M1)**
	no temperature rise so kinetic energy (of molecules) unchanged	**(M1)**
	so internal energy does not change	**(A1)**

Question	Answer	Marks
3(a)(i)	amplitude = 4.9 cm	**A1**
3(a)(ii)	frequency = 2700 / 60 = 45 Hz	**A1**
3(a)(iii)	$v_0 = x_0\omega$ **and** $\omega = 2\pi f$	**C1**
	$v_0 = 4.9 \times 10^{-2} \times 2\pi \times 45$ $= 14\ \text{m s}^{-1}$	**A1**
3(a)(iv)	$v = \omega (x_0^2 - x^2)^{½}$ $= 2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{½}$	**C1**
	$= 12\ \text{m s}^{-1}$	**A1**

Question	Answer	Marks
3(b)	$F = ma$ **and** $a_0 = v_0\omega$ **or** $a_0 = x_0\omega^2$	C1
	$F = 0.64 \times 13.9 \times 2\pi \times 45$ **or** $0.64 \times 4.9 \times (2\pi \times 45)^2$	C1
	= 2500 N	A1

Question	Answer	Marks
4(a)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
4(a)(ii)	the greater the difference between Z_1 and Z_2, the closer the ratio is to 1 **or** if difference between Z_1 and Z_2 large, ratio is close to 1	B1
	the closer together Z_1 and Z_2, the closer the ratio is to 0 **or** if difference between Z_1 and Z_2 small, ratio close to 0	B1
4(b)(i)	loss of intensity/amplitude/power (of the wave)	B1
4(b)(ii)	$I = I_0 e^{-\mu x}$	C1
	$0.35 = e^{-0.046\mu}$ $\mu = 23\ m^{-1}$	A1

Question	Answer	Marks
5(a)	similarity: both are radial **or** both have inverse square (variations)	**B1**
	difference: direction is always/only towards the mass **or** direction can be towards or away from charge	**B1**
5(b)	field strength = $Q / 4\pi\varepsilon_0 x^2$	**C1**
	$E = Q / 36\pi\varepsilon_0 R^2$	**A1**
5(c)(i)	fields (due to each sphere) are in same direction	**B1**
5(c)(ii)	charges on spheres attract/affect each other **or** charge distribution on each sphere distorted by the other sphere **or** charges on the surface of the spheres move	**B1**
	spheres are not point charges (at their centres)	**B1**

Question	Answer	Marks
6(a)(i)	greater information carrying capacity	**B1**
6(a)(ii)	power/energy is radiated	**B1**
	signal picked up by adjacent fibre/wire	**B1**
6(b)	ratio / dB = 10 lg(P_2 / P_1)	**C1**
	13 = 10 lg [P / (1.0 × 10^{-3})] and so P = 20 mW	**A1**
6(c)	45 × 0.18 = 10 lg (20 / P)	**C1**
	P = 3.1 mW	**A1**

Question	Answer	Marks
7(a)	output signal proportional to input signal	**B1**
	output signal has same sign/polarity as input signal	**B1**
7(b)(i)	gain $= V_{OUT} / V_{IN}$ $= 2.6 / 0.084$ $= 31$	**A1**
7(b)(ii)	$31 = 1 + (15 \times 10^3) / R$	**C1**
	$R = 500\ \Omega$	**A1**
7(c)(i)	e.g. cathode-ray oscilloscope/CRO	**B1**
7(c)(ii)	gain is reduced	**B1**
	(so) V_{OUT} is smaller	**B1**

Question	Answer	Marks
8(a)	magnetic field normal to current	**B1**
	newton per ampere	**B1**
	newton per metre	**B1**
8(b)(i)	current in wire QL gives rise to a force **or** wire QL is perpendicular to the magnetic field	**B1**
	force on wire QL is vertical	**B1**
	force does not act through the pivot	**B1**
8(b)(ii)	forces act through the same line **or** forces are horizontal	**B1**
	forces are equal (in magnitude) and opposite (in direction)	**B1**
8(c)(i)	change $= mg \times (\Delta)L$	**C1**
	$= 1.3 \times 10^{-4} \times 9.81 \times 2.6 \times 10^{-2} = 3.3 \times 10^{-5}\ \text{N m}^{-1}$	**A1**
8(c)(ii)	change $= B \times (\Delta)I \times L \times x$	**C1**
	$3.3 \times 10^{-5} = B \times 1.2 \times 0.85 \times 10^{-2} \times 5.6 \times 10^{-2}$	**C1**
	$B = 0.058\ \text{T}$	**A1**

Question	Answer	Marks
9(a)(i)	e.m.f. $= (\Delta)B \times AN / t$	C1
	$= 45 \times 10^{-3} \times \pi \times (1.8 \times 10^{-2})^2 \times 350 / 0.20 = 0.080$ V	A1
9(a)(ii)	0 to 0.2 s: straight horizontal line at 0.080 V or –0.080 V	B1
	0.2 s to 0.4 s: zero	B1
	0.4 s to 0.8 s: straight horizontal line at 0.040 V or –0.040 V	B1
	opposite polarity to 0 to 0.2 s line	B1
9(b)	either disc cuts flux lines (of the magnet) **or** there is a changing flux in the disc	B1
	(by Faraday's law) e.m.f. is induced in the disc	B1
	e.m.f. causes (eddy) currents in the disc	B1
	current in the magnetic field (of the magnet) causes force on disc	B1

Question	Answer	Marks
10(a)	• photon gives energy to electron (in an inner shell) **or** electron (in an inner shell) absorbs a photon • electron moves (from lower) to higher energy level • energy (of photon) is equal to difference in energy levels • electron de-excites giving off photon (of same energy) • photons emitted in all directions *Any four points, 1 mark each*	**B4**
10(b)	(in light) photons gives energy to electrons in VB **or** (in light) electrons in VB absorb photons	**B1**
	electron crosses FB/jumps to CB	**B1**
	(positive) holes left/created in VB	**B1**
	low intensity: few electrons in CB/most electrons in VB **or** high intensity: more photons so more electrons in CB **or** electron-hole pairs are charge carriers	**B1**
	more charge carriers results in lower resistance	**B1**

Question	Answer	Marks
11(a)(i)	$E = mc^2$	**C1**
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$ $= 8.2 \times 10^{-14}$ J	**A1**
11(a)(ii)	$p = h / \lambda$ **and** $E = hc / \lambda$ **or** $E = pc$	**C1**
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$ $= 2.7 \times 10^{-22}$ N s	**A1**
11(b)	total momentum (before and after interaction) is zero **or** momentum must be conserved (in the interaction) **or** momentum of the photons must be equal and opposite	**B1**
	(photons emitted in) opposite directions	**B1**

Question	Answer	Marks
12(a)(i)	time at which a nucleus will decay cannot be predicted **or** constant probability of decay of a nucleus	B1
12(a)(ii)	decay (of a nucleus) not affected by environmental factors	B1
12(b)	$A = A_0 e^{-\lambda t}$ **and** $\lambda = \ln 2 / t_{½}$	C1
	$= 3.6 \times 10^5 \times \exp[-(2 \times \ln 2) / 1.4]$	C1
	or	
	$A = A_0 \times 0.5^N$	(C1)
	$= 3.6 \times 10^5 \times 0.5^N$ where $N = 2 / 1.4$	(C1)
	$A = 1.3 \times 10^5$ Bq	A1
12(c)(i)	smooth curve, starting at (0, 3.6×10^5) and passing through (1.4, 1.8×10^5) and (2.0, 1.3×10^5)	B1
12(c)(ii)	(activity of sample is greater than activity of X so) there must be an additional source of activity	C1
	the decay product (of isotope X) is radioactive	A1

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS	**9702/43**
Paper 4 A Level Structured Questions	**October/November 2018**
MARK SCHEME	
Maximum Mark: 100	

Published

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Question	Answer	Marks
1(a)(i)	work done per unit mass	**B1**
	work done moving mass from infinity (to the point)	**B1**
1(a)(ii)	(near Earth's surface change in) height $\ll$ radius **or** height <u>much</u> less than radius	**B1**
	potential inversely proportional to radius **and** radius approximately constant (so potential approximately constant)	**B1**
1(b)	initial kinetic energy = (–) potential energy (at surface) **or** $\frac{1}{2}mv^2 = GMm/r$	**B1**
	$v^2 = (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22})/(0.5 \times 3.5 \times 10^6)$	**C1**
	$v = 2.4 \times 10^3\,\text{m s}^{-1}$	**A1**

Question	Answer	Marks
2(a)	sum of potential and kinetic energies (of molecules/atoms/particles)	**B1**
	(energy of) molecules/atoms/particles in random motion	**B1**
2(b)(i)	final temperature = initial temperature	**B1**
	no change in internal energy	**B1**
2(b)(ii)	**1.** work done on gas (P→Q): 0	**A1**
	increase in internal energy (P→Q): (+)97.0 J	**A1**
	2. increase in internal energy (Q→R): –42.5 J	**A1**
	3. increase in internal energy (R→P): –54.5 J	**A1**
	thermal energy supplied (R→P): –91.5 J	**A1**

Question	Answer	Marks
3(a)	$\omega^2 = 2g / L$	C1
	$T = 2\pi / \omega$	C1
	$\omega^2 = (2 \times 9.81) / 0.19$ $\omega = 10.2$ (rad s^{-1}) $T = 2\pi / 10.2$ $= 0.62$ s	A1
3(b)(i)	e.g. viscosity of liquid/friction within the liquid/viscous drag/friction between walls of tube and liquid	B1
3(b)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2 x_0^2$	C1
	change = $\frac{1}{2} \times 18 \times 10^{-3} \times 103 \times [(2.0 \times 10^{-2})^2 - (0.95 \times 10^{-2})^2]$	C1
	$= 2.9 \times 10^{-4}$ J	A1

Question	Answer	Marks
4(a)	pulses (of ultrasound from generator)	**B1**
	reflected at boundaries (between media)	**B1**
	time delay (between transmission and receipt) gives information about depth	**B1**
	intensity of reflected pulse gives information about nature (of tissues)/type (of tissues)/boundary	**B1**
	Any two from: • (reflected pulses) detected by the (ultrasound) generator • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	**B2**
4(b)(i)	product of density and speed	**M1**
	speed of ultrasound in medium	**A1**
4(b)(ii)	Z_1 about equal to Z_2 results in negligible/no reflection	**B1**
	$Z_1 \gg Z_2$ (or $Z_1 \ll Z_2$) results in mostly reflection	**B1**

Question	Answer	Marks
5(a)	Any two reasonable suggestions e.g.: • noise can be eliminated/(signal/data) can be regenerated • bits can be added to correct for errors • data compression/multiplexing (is possible) • signal can be encrypted/better security	**B2**
5(b)	sketch: series of seven steps	**B1**
	each step width 2 ms	**B1**
	correct levels in correct order (2, 5, 14, 4, 9, 11, 7) (*1 mark for 6 levels correct, 2 marks for 7 levels correct*)	**A2**
5(c)(i)	step width reduced **or** higher frequencies can be reproduced	**B1**
5(c)(ii)	step height reduced **or** smaller <u>changes</u> in signal (intensity) can be reproduced	**B1**

Question	Answer	Marks
6(a)(i)	work done per unit charge	**B1**
	work done moving positive charge from infinity (to the point)	**B1**
6(a)(ii)	field strength = potential gradient	**M1**
	'–' sign included **or** directions discussed	**A1**
6(b)(i)	gain in kinetic energy (= loss in potential energy) = charge × p.d. **or** $qV = \frac{1}{2}mv^2$	**M1**
	so v is independent of separation (because separation not in expressions)	**A1**

Question	Answer	Marks
6(b)(ii)	(at x = 0.40 cm), potential = (–) 75 × 0.40 / 1.2 (= (–) 25 V)	**C1**
	$\frac{1}{2}mv^2 = qV$ $\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 25$	**C1**
	or	
	$a = Vq / dm$ **and** $v^2 = 2as$	**(C1)**
	$v^2 = (2 \times 75 \times 2 \times 1.60 \times 10^{-19} \times 0.40 \times 10^{-2}) / (1.2 \times 10^{-2} \times 4 \times 1.66 \times 10^{-27})$	**(C1)**
	$v = 4.9 \times 10^4\,\text{m s}^{-1}$	**A1**

Question	Answer	Marks
7(a)(i)	gain is constant	**M1**
	for all frequencies	**A1**
7(a)(ii)	no time delay between input (voltage) and output (voltage)	**B1**
	clear reference to <u>change</u>(s) in input and/or output (voltages)	**B1**
7(b)	diagram: V_{IN} connected to V^+ only	**B1**
	midpoint between resistors R_1 and R_2 connected to V^- only	**B1**
7(c)(i)	–3.6 V	**A1**
7(c)(ii)	(+)5.0 V	**A1**

Question	Answer	Marks
8(a)	region where there is a force	**M1**
	experienced by a current-carrying conductor/moving charge/(permanent) magnet	**A1**
8(b)(i)	single path, deflection in 'upward' direction	**B1**
	acceptable circular arc in whole field	**B1**
	no 'kinks' at start or end of curvature, and straight outside region of field	**B1**
8(b)(ii)	force (on particle) is normal to velocity/direction of motion/direction of speed	**B1**
8(c)	magnetic force provides/is the centripetal force	**B1**
	$Bqv = mv^2 / r$ **or** $r = mv / Bq$	**C1**
	(if q is doubled), new speed = 2v	**A1**

Question	Answer	Marks
9(a)	(induced) e.m.f. proportional/equal to <u>rate</u>	**M1**
	of change of (magnetic) flux (linkage)	**A1**
9(b)(i)	induced e.m.f. $= (\Delta B)AN / \Delta t$ $= (2 \times 0.19 \times 1.5 \times 10^{-4} \times 120) / 0.13$	**C1**
	$= 0.053\,\text{V}$	**A1**
9(b)(ii)	reading on voltmeter connected to coil C / V: 0 0.053 0 (*all three values required*)	**A1**
	reading on voltmeter connected to Hall probe / V: zero in middle column	**B1**
	final column correct sign (negative)	**B1**
	final column correct magnitude (0.20)	**B1**

Question	Answer	Marks
10	Any five points from: • as temperature rises electrons gain energy • electrons enter conduction band • (positively charged) holes left in valence band • more charge carriers (so resistance decreases) • (as temperature rises,) lattice vibrations increase • effect of increase in number of electrons or holes or charge carriers outweighs effect of increased lattice vibrations (so resistance decreases)	**B5**

Question	Answer	Marks
11(a)	discrete amount/quantum/packet of <u>energy</u>	**M1**
	of electromagnetic radiation	**A1**
11(b)(i)	energy = hc/λ	**C1**
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8})/(0.51 \times 10^{6} \times 1.60 \times 10^{-19})$ $= 2.4 \times 10^{-12}$ m	**A1**
11(b)(ii)	$p = h/\lambda$ $= (6.63 \times 10^{-34})/(2.44 \times 10^{-12})$ **or** $p = E/c$ $= (0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^{8})$	**C1**
	$p = 2.7 \times 10^{-22}$ N s	**A1**
11(c)(i)	$E = c^2 \Delta m$	**C1**
	$\Delta m = (0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^{8})^2$ $= 9.1 \times 10^{-31}$ kg	**A1**
11(c)(ii)	(momentum is conserved so) nucleus must have momentum in opposite direction to photon	**B1**

Question	Answer	Marks
12(a)	unstable nucleus	**B1**
	emission of particles/photons	**B1**
	emission is spontaneous **or** (particles/radiation) are ionising	**B1**
12(b)(i)	tangent drawn and gradient calculation attempted	**B1**
	activity = 1.3×10^6 Bq (*1 mark for answer within* $\pm 0.2 \times 10^6$ Bq*, 2 marks for answer within* $\pm 0.1 \times 10^6$ Bq)	**A2**
12(b)(ii)	$A = \lambda N$	**C1**
	$\lambda = (1.3 \times 10^6) / (3.05 \times 10^{10}) = 4.3 \times 10^{-5}\,\text{s}^{-1}$ ($\approx 4 \times 10^{-5}\,\text{s}^{-1}$)	**A1**
12(c)	$A = A_0 e^{-\lambda t}$ $1.0 \times 10^3 = 4.6 \times 10^3 \exp(-5.5 \times 10^{-7} \times t)$	**C1**
	$\ln(4.6) = 5.5 \times 10^{-7} \times t$	**C1**
	$t = 2.78 \times 10^6$ s = 32 days	**A1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS	**9702/43**
Paper 4 A Level Structured Questions	**October/November 2019**
MARK SCHEME	
Maximum Mark: 100	

Published

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- the specific skills defined in the mark scheme or in the generic level descriptors for the question
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- marks are not deducted for omissions
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GENERIC MARKING PRINCIPLE 4:

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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.

Question	Answer	Marks
1(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of (gravitational) force between point masses	B1
1(b)(i)	above the equator	B1
	from west to east	B1
1(b)(ii)	gravitational force provides/is the centripetal force	B1
	$GM / r^2 = r (2\pi / T)^2$	C1
	$(6.67 \times 10^{-11} \times M) = \{(4.23 \times 10^7)^3 \times 4\pi^2\} / (24 \times 3600)^2$	C1
	$M = 6.0 \times 10^{24}$ kg	A1

Question	Answer	Marks
2(a)	(total volume of molecules is) negligible	**M1**
	compared with volume occupied by the gas	**A1**
2(b)(i)	$pV = NkT$	**C1**
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = N \times 1.38 \times 10^{-23} \times (273 + 23)$	**C1**
	or	
	$pV = nRT$	**(C1)**
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (273 + 23)$ $n = 4.49$ (mol) $N = nN_A$ $= 4.49 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.7 \times 10^{24}$	**A1**

Question	Answer	Marks
2(b)(ii)	volume of one atom = d^3 (= 2.7×10^{-29} m^3)	C1
	volume of all atoms = $2.7 \times 10^{-29} \times 2.7 \times 10^{24}$	C1
	= 7×10^{-5} m^3	A1
	or	
	volume of one atom = $(4 / 3)\pi r^3$ (= 1.41×10^{-29} m^3)	(C1)
	volume of all atoms = $2.7 \times 10^{24} \times 1.41 \times 10^{-29}$	(C1)
	= 4×10^{-5} m^3	(A1)
2(c)	numerical comparison between answer to **(b)(ii)** and 2.4×10^{-2} (m^3) showing **(b)(ii)** is <u>much</u> less than 2.4×10^{-2} (m^3)	B1

Question	Answer	Marks
3(a)	(thermal) energy per (unit) mass (to change state)	**B1**
	(heat transfer during) change of state at constant temperature	**B1**
3(b)(i)	32 g	**A1**
3(b)(ii)	temperature difference (between liquid and surroundings) does not change	**B1**
3(b)(iii)	$VIt = mL$	**C1**
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$ **or** $190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	**C1**
	$86 \times 600 = (56 - 32) \times L$	**C1**
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	**(C1)**
	$276 - 190 = (24 \times L) / 600$	**(C1)**
	$L = 2200\ \text{J g}^{-1}$	**A1**

Question	Answer	Marks
3(b)(iv)	$230 \times 1.2 \times 600 = (56 \times 2150) + H$ **or** $190 \times 1.0 \times 600 = (32 \times 2150) + H$	**C1**
	$H = 45\,200$ rate $= 45\,200 / 600$ $= 75$ W	**A1**
	or	
	$230 \times 1.2 = (56 \times 2150) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times 2150) / (60 \times 10) + P$	**(C1)**
	rate (= P) = 75 W	**(A1)**

Question	Answer	Marks
4(a)(i)	distance from a (reference) point in a given direction	**B1**
4(a)(ii)	line is not straight **or** gradient is not constant	**B1**
4(b)(i)	0.85–0.90 cm	**A1**
4(b)(ii)	$a = -(2\pi f)^2 x$	**C1**
	e.g. $1.2 = 4\pi^2 \times f^2 \times (0.90 \times 10^{-2})$	**C1**
	$f = 1.8$ Hz	**A1**
4(c)	complete circle/ellipse enclosing the origin	**B1**
	closed shape passing through $(0, \pm v_0)$ and $(\pm x_0, 0)$	**B1**

Question	Answer	Marks
5(a)(i)	provides return for the signal	**B1**
	shields signal from noise	**B1**
5(a)(ii)	e.g. connection between aerial and TV set	**B1**
5(b)(i)	gain / dB = 10 lg (P_1 / P_2)	**C1**
	32 = 10 lg {P_{MIN} / (7.6 × 10^{-6})} P_{MIN} = 0.012 W	**A1**
5(b)(ii)	attenuation per unit length = (1 / L) × 10 lg (P_1 / P_2) 6.3 = (1 / L) × 10 lg (2.6 / 0.012)	**C1**
	L = 3.7 km	**A1**

Question	Answer	Marks
6(a)	$(E =)\ Q / 4\pi\varepsilon_0 r^2$	**M1**
	where ε_0 is permittivity (of free space)	**A1**
6(b)(i)	field does not change direction/field does not become zero	**M1**
	so (charges have) opposite (sign)	**A1**
6(b)(ii)	minimum is at the midpoint (between the charges)	**M1**
	so (magnitudes are the) same	**A1**
6(c)	force = field strength × charge **and** force = mass × acceleration **or** acceleration is proportional to field strength	**B1**
	(from $x = 3.0$ cm) to $x = 5.0$ cm: acceleration decreases	**B1**
	at $x = 5.0$ cm: acceleration is a minimum	**B1**
	from $x = 5.0$ cm (to $x = 7.0$ cm): acceleration increases	**B1**

Question	Answer	Marks
7(a)(i)	all frequencies are amplified equally	B1
7(a)(ii)	no drop in output voltage (when there is a current)	B1
7(b)(i)	gain = 1 + R_F / R_{IN} = 1 + (4000 / 800)	C1
	= 6.0	A1
7(b)(ii)	2.0 / V_{IN} = 6.0 V_{IN} = (+)0.33 V	A1
7(b)(iii)	5.0 V	A1
7(b)(iv)	V = 5.0 – 2.2 (= 2.8 V)	C1
	R = V / I = 2.8 / 0.020 = 140 Ω	A1

Question	Answer	Marks
8(a)	concentric circles (around the wire)	**M1**
	at least 3 circles shown, all with increasing separation	**A1**
	direction anticlockwise	**B1**
8(b)(i)	$B = (4\pi \times 10^{-7} \times 6.2) / (2\pi \times 3.1 \times 10^{-2})$	**C1**
	$= 4.0 \times 10^{-5}$ T	**A1**
8(b)(ii)	$F = BIL$ **or** $F / L = BI$	**C1**
	$F / L = 4.0 \times 10^{-5} \times 8.5$ $= 3.4 \times 10^{-4}$ N m^{-1}	**A1**
8(c)	correct application of Newton's 3rd law to the forces **or** F / L is proportional to the product of the two currents	**M1**
	so same magnitude	**A1**

Question	Answer	Marks
9(a)	nuclei precess	**B1**
	precession is about (direction of magnetic) field **or** frequency of precession is in radio-frequency range	**B1**
9(b)	• frequency (of precession) depends on field strength • to locate/find position of (spinning) nuclei • to change region where nuclei are detected *any two points, one mark each*	**B2**

Question	Answer	Marks
10(a)(i)	lower right **and** upper left diodes circled	**B1**
10(a)(ii)	maximum = 7.0√2 = 9.9 V	**A1**
10(b)(i)	correct symbol for capacitor, shown connected in parallel with R	**B1**
10(b)(ii)	**1.** (ripple) decreases	**B1**
	2. (ripple) increases	**B1**

Question	Answer	Marks
11(a)	energy (of photon) required to remove electron	**M1**
	from a surface **or** reference to <u>minimum</u> energy **or** reference to zero <u>kinetic</u> energy	**A1**
11(b)(i)	**1.** photon energy $= hc / \lambda$	**C1**
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (280 \times 10^{-9})$ $= 7.1 \times 10^{-19}$ J	**A1**
	2. electron energy $= (7.1 - 5.5) \times 10^{-19}$ J	**C1**
	$½ \times 9.11 \times 10^{-31} \times v^2 = (7.1 - 5.5) \times 10^{-19}$	**C1**
	$v = 5.9 \times 10^{5}$ m s^{-1}	**A1**
11(b)(ii)	energy is required to bring electron to the surface	**B1**
11(c)	<table><tr><td>no change</td><td>decreases</td></tr><tr><td>increases</td><td>decreases</td></tr></table>	**B4**

Question	Answer	Marks
12(a)	$E = (3.0 \times 10^8)^2 \times 1.66 \times 10^{-27}$ (= 1.49×10^{-10} J)	**M1**
	= $(1.49 \times 10^{-10}) / (1.60 \times 10^{-19}) = 9.34 \times 10^8$ = 934 MeV	**A1**
	or	
	binding energy = 8.443×95 [or equivalent using La-139 nucleus]	**(M1)**
	binding energy / mass defect = $(8.443 \times 95) / 0.859$ = 934 MeV	**(A1)**
12(b)(i)	binding energy = 1.865×934 (= 1741.91 MeV)	**C1**
	binding energy per nucleon = 1741.91 / 235 = 7.41 (MeV)	**A1**
12(b)(ii)	less (than)	**B1**
12(c)	energy = $\{(1.219 + 0.859) – 1.865)\} \times 934$ **or** energy = $(95 \times 8.443) + (139 \times 8.189) – (235 \times 7.412)$	**C1**
	= 199 MeV	**A1**
12(d)	number of reactions = $1.2 \times 10^{-7} \times 6.02 \times 10^{23}$ = 7.22×10^{16}	**C1**
	energy release (for one reaction) = $199 \times 1.60 \times 10^{-13}$ (= 3.18×10^{-11} J)	**C1**
	power = $(7.22 \times 10^{16} \times 3.18 \times 10^{-11}) / (25 \times 10^{-3})$ = 9.2×10^7 W	**A1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS	**9702/42**
Paper 4 A Level Structured Questions	**October/November 2019**
MARK SCHEME	
Maximum Mark: 100	

Published

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Question	Answer	Marks
1(a)	force proportional to product of masses and inversely proportional to square of separation	**B1**
	idea of (gravitational) force between point masses	**B1**
1(b)	gravitational force provides/is the centripetal force	**B1**
	$GM / R^2 = R\omega^2$ **or** $GM / R^2 = v^2 / R$	**M1**
	$\omega = 2\pi / T$ **or** $v = 2\pi R / T$	**M1**
	algebra leading to $R^3/T^2 = GM / 4\pi^2$	**A1**
1(c)	$(6.67 \times 10^{-11} \times M) / 4\pi^2 = (4.38 \times 10^6)^3 / (2.44 \times 3600)^2$	**C1**
	$M = 6.45 \times 10^{23}$ kg	**A1**

Question	Answer	Marks
2(a)(i)	specks of light moving haphazardly	**B1**
2(a)(ii)	(gas) molecules collide with (smoke) particles **or** random motion of the (gas) molecules	**M1**
	causes the (haphazard) motion of the smoke particles **or** causes the smoke particles to change direction	**A1**
2(b)(i)	$pV = nRT$	**C1**
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 290)$ **or** $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 310)$	**C1**
	or	
	$pV = NkT$	**(C1)**
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 290)$ **or** $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 310)$	**(C1)**
	$n = 0.350$ mol **or** 0.349 mol	**A1**
2(b)(ii)	energy transfer = (0.349 **or** 0.35) × 12.5 × (310 – 290)	**C1**
	= 87.3 J **or** 87.5 J	**A1**
2(c)(i)	zero	**A1**
2(c)(ii)	87.3 J **or** 87.5 J	**A1**
	increase	**B1**

Question	Answer	Marks
3(a)	(thermal) energy per unit mass (to change state)	**B1**
	change of state without any change of temperature	**B1**
3(b)(i)	140 g	**A1**
3(b)(ii)	temperature difference (between apparatus and surroundings) does not change	**B1**
3(b)(iii)	$VIt = mL$	**C1**
	$(\{15.1 \times 3.6\} + R) \times 600 = 140 \times L$ **or** $(\{7.3 \times 1.8\} + R) \times 600 = 65 \times L$	**C1**
	$41.22 \times 600 = 75 \times L$	**C1**
	$L = 330\ \text{J g}^{-1}$	**A1**
3(b)(iv)	$15.1 \times 3.6 \times 600 = (140 \times 330) - H$ **or** $7.3 \times 1.8 \times 600 = (65 \times 330) - H$	**C1**
	$H = 13\,600$ rate of gain = 13 600 / 600 = 23 W	**A1**

Question	Answer	Marks
4(a)(i)	loss of energy	**B1**
4(a)(ii)	amplitude (of oscillations) decreases (with time)	**B1**
4(b)(i)	$\omega = 2\pi / T$	**C1**
	$T = 0.80$ s, so $\omega = 2\pi / 0.80$ $\omega = 7.9$ rad s^{-1}	**A1**
4(b)(ii)	$\omega^2 = 2k / M$	**C1**
	$7.9^2 = 2k / 1.2$ $k = 37$ N m^{-1}	**A1**
4(c)(i)	(one) smooth curve, not touching the *f*-axis, with two concave sides meeting at a peak in between them	**B1**
	(one) peak at 1.0ω	**B1**
4(c)(ii)	• lower peak/(whole) line is lower • flatter <u>peak</u>/<u>peak</u> is less sharp • peak at (slightly) lower angular frequency/peak moves to left *any two points, one mark each*	**B2**

Question	Answer	Marks
5(a)(i)	product of density and speed	**M1**
	speed of sound in the medium	**A1**
5(a)(ii)	$Z_B = 1.8 \times 10^3 \times 4.1 \times 10^3$ $= 7.4 \times 10^6\ \text{kg m}^2\ \text{s}^{-1}$	**A1**
5(b)	$\alpha = (1.7 - 1.3)^2 / (1.7 + 1.3)^2 = 0.018$ fraction = 0.98	**A1**
5(c)(i)	reduction in power/intensity (of wave)	**M1**
	as the wave passes through the medium	**A1**
5(c)(ii)	**1.** ratio $= e^{-\mu x}$	**C1**
	$= 0.90$	**A1**
	2. ratio $= 0.62$	**A1**
5(d)	fraction $= 0.898 \times 0.617 \times 0.98$ $= 0.54$	**A1**

Question	Answer	Marks
6(a)	period = 5.0 μs, so frequency = 2.0×10^5 Hz	**A1**
6(b)	sketch: three equally spaced vertical lines sitting on *f*-axis	**B1**
	two outer vertical lines of equal length and central line longer	**B1**
	three vertical lines (and no others) shown at frequencies 190 kHz, 200 kHz and 210 kHz	**B1**

Question	Answer	Marks
7	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**

Question	Answer	Marks
8(a)	magnitude: (force =) Bqv	**B1**
	direction: P→Q **or** E→F **or** S→R **or** H→G	**B1**
8(b)(i)	EHSP and FGRQ	**B1**
8(b)(ii)	PE **or** QF **or** RG **or** SH	**B1**
8(c)(i)	*any one correct starting point from:* • (mass of 1 atom =) $27 \times 1.66 \times 10^{-27}$ • (amount of substance per unit volume =) 2.7 / 27 • 27 g (of substance) contains 6.02×10^{23} atoms • (2.7 g mass contains) 0.1 mol • (1 cm^3 volume contains) 0.1 mol • (1 m^3 volume contains) 10^5 mol	**C1**
	$n = (2.7 \times 10^3) / (27 \times 1.66 \times 10^{-27}) = 6.0 \times 10^{28}$ **or** $n = (2.7 / 27) \times 10^6 \times 6.02 \times 10^{23} = 6.0 \times 10^{28}$	**A1**
8(c)(ii)	$V_H = (0.15 \times 4.6) / (6.0 \times 10^{28} \times 0.090 \times 10^{-3} \times 1.60 \times 10^{-19})$	**C1**
	$= 8.0 \times 10^{-7}$ V	**A1**

Question	Answer	Marks
9(a)	work done per unit charge	**B1**
	(work done) moving positive charge from infinity	**B1**
9(b)(i)	energy $= 4.8 \times 1.60 \times 10^{-13}$ $= 7.7 \times 10^{-13}$ J	**A1**
9(b)(ii)	$E_P = Qq / 4\pi\varepsilon_0 d$	**C1**
	$Q = 79e$ **and** $q = 2e$	**C1**
	$7.68 \times 10^{-13} = (79 \times 2 \times \{1.60 \times 10^{-19}\}^2 / (4\pi \times 8.85 \times 10^{-12} \times d)$	**C1**
	$d = 4.7 \times 10^{-14}$ m	**A1**
9(c)	(diameter must be) less than/equal to 10^{-13} or 10^{-14} m	**B1**

Question	Answer	Marks
10(a)	(as temperature rises) electrons in valence band gain energy	**B1**
	electrons jump to conduction band	**B1**
	holes are left in the valence band	**B1**
	increased <u>number</u> (density) of charge carriers causes lower resistance	**B1**
10(b)(i)	$V^- = V^+$	**C1**
	$1.50 / 1.20 = R_T / 1.76$	**C1**
	$R_T = 2.2$ (kΩ)	**C1**
	temperature = 14 °C	**A1**
10(b)(ii)	(For LED to conduct,) V_{OUT} must be negative	**B1**
	$V^- > V^+$	**B1**
	R_T must be lower so temperature must be above **(b)(i)** value	**B1**

Question	Answer	Marks
11(a)	(induced) e.m.f. proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
11(b)(i)	any two from t_1, t_3, t_5, t_7	**A1**
11(b)(ii)	t_2 **and** t_4 **or** t_4 **and** t_6	**A1**
11(c)	e.m.f. = $N\Delta\Phi / \Delta t$	**C1**
	$= (2 \times 9.4 \times 10^{-4} \times 5.0 \times \pi \times (1.8 \times 10^{-2})^2 \times 63) / (6.0 \times 10^{-3})$	**C1**
	= 0.10 V	**A1**

Question	Answer	Marks
12(a)(i)	(decay is) unpredictable/cannot be predicted	**B1**
12(a)(ii)	probability of decay (of a nucleus)	**M1**
	per unit time	**A1**
12(b)	$A = \lambda N$	**C1**
	(for 1.00 m^3) $A = 0.600 / 4.80 \times 10^{-3}$ (= 125 Bq)	**C1**
	$N = 125 / ([7.55 \times 10^{-3}] / 3600)$ (= 5.96×10^7)	**C1**
	so ratio = $(2.52 \times 10^{25}) / (5.96 \times 10^7)$	**C1**
	or	
	(for 4.80×10^{-3} m^3) N for air = $2.52 \times 10^{25} \times 4.80 \times 10^{-3}$ (= 1.21×10^{23})	**(C1)**
	N for radon = $0.600 / ([7.55 \times 10^{-3}] / 3600)$ (= 2.86×10^5)	**(C1)**
	so ratio = $(1.21 \times 10^{23}) / (2.86 \times 10^5)$	**(C1)**
	ratio = 4.2×10^{17}	**A1**

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

PHYSICS	**9702/42**
Paper 4 A Level Structured Questions	**October/November 2018**
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 October/November 2018 series for most Cambridge IGCSE™, Cambridge International A and AS Level components and some Cambridge O Level components.

Cambridge Assessment International Education

Generic Marking Principles

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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.

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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.

Question	Answer	Marks
1(a)(i)	force per unit mass	**B1**
1(a)(ii)	acceleration = F/m, field strength = F/m, so equal	**B1**
1(b)	smooth curve between R and $4R$ with negative gradient of decreasing magnitude	**B1**
	line passing through (R, 1.00g) and (2R, 0.25g)	**B1**
	line ending at (4R, 0.0625g)	**B1**
1(c)	$M = (4/3 \times \pi R^3)\rho$	**C1**
	$g = GM/(2R)^2$	**C1**
	$g = ⅓ \times 6.67 \times 10^{-11} \times \pi \times 3.4 \times 10^6 \times 4.0 \times 10^3$ $= 0.95\,\text{m s}^{-2}$	**A1**

Question	Answer	Marks
2(a)	gas that obeys equation pV = constant × T	**M1**
	symbols p, V and T explained	**A1**
2(b)(i)	$pV = ⅓ Nm<c^2>$ **and** $M = Nm$ (and so) $p = ⅓\rho<c^2>$	**C1**
	$2.12 \times 10^7 = ⅓ \times [3.20 / (1.84 \times 10^{-2})] \times <c^2>$	**C1**
	$c_{r.m.s.} = 605\,m\,s^{-1}$	**A1**
2(b)(ii)	**1.** $pV = nRT$ **and** $T = (22 + 273)\,K$	**C1**
	$n = (2.12 \times 10^7 \times 1.84 \times 10^{-2}) / (8.31 \times 295)$ $= 159\,mol$	**A1**
	2. mass = $3.20 / (159 \times 6.02 \times 10^{23})$ **or** mass = $[2 \times (3/2) \times 1.38 \times 10^{-23} \times 295] / 605^2$	**C1**
	mass = $3.34 \times 10^{-26}\,kg$	**A1**
2(c)	$A = (3.34 \times 10^{-26}) / (1.66 \times 10^{-27})$ $= 20$	**A1**

Question	Answer	Marks
3(a)	(thermal) energy per unit mass (to cause change of state)	**B1**
	(energy transfer during) change of state between solid and liquid at constant temperature	**B1**
3(b)(i)	Any one from: • rate of increase in mass (of beaker and water) is constant • level of water rises at a constant rate • volume of water (in beaker) increases at a constant rate • constant time between drops • constant rate of dripping	**B1**
3(b)(ii)	(electrical power supplied =) 12.8 × 4.60 (= 58.9 W)	**C1**
	(rate of transfer to ice =) [(185.0 – 121.5) × 332] / [5.00 × 60] (= 70.3 W)	**C1**
	1. rate = 70.3 W	**A1**
	2. rate = 70.3 – 58.9 = 11.4 W	**A1**

Question	Answer	Marks
4(a)	(defining equation of s.h.m. is) $a = -kx$ where k is a constant **or** $a \propto -x$	B1
	g and L are constant (so $a \propto -x$ and hence s.h.m.)	B1
4(b)	$T = 0.50\,\text{s}$ **and** $T = 2\pi / \omega$	C1
	$\omega^2 = 2g / L$	C1
	$L = (2 \times 9.81 \times 0.50^2) / 4\pi^2$ $= 0.12\,\text{m}$	A1
4(c)(i)	Any one from: • viscosity of liquid • friction within the liquid • viscous drag • friction/resistance between walls of tube and liquid	B1
4(c)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2x_0^2$	C1
	ratio = $(1.3 / 2.0)^2$ $= 0.42$	A1

Question	Answer	Marks
5(a)	amplitude of carrier (wave) varies	**B1**
	variation in synchrony with displacement of information signal	**B1**
5(b)(i)	wavelength = $(3.0 \times 10^8) / (900 \times 10^3)$ $= 3.3 \times 10^2$ m	**A1**
5(b)(ii)	amplitude varies (continuously) between a maximum and a minimum	**B1**
	variations repeat 5000 times each second **or** variations repeat every 0.2 ms **or** variations above and below 4.0 V	**B1**
5(b)(iii)	10000 Hz	**A1**
5(c)(i)	Any two from: • (orbit is) above the Equator • (orbit is) from west to east/same direction as Earth's rotation • orbit is circular/orbit has a particular radius	**B2**
5(c)(ii)	**1.** minimal reflection/absorption/attenuation by <u>atmosphere</u> **or** maximum penetration of/transmission through <u>atmosphere</u>	**B1**
	2. uplink signal is greatly attenuated/must be greatly amplified	**B1**
	prevents downlink signal swamping the uplink signal	**B1**

Question	Answer	Marks
6(a)(i)	work done per unit charge	**B1**
	work done moving positive charge from infinity (to the point)	**B1**
6(a)(ii)	field strength = potential gradient	**M1**
	negative sign included **or** directions discussed	**A1**
6(b)	horizontal straight lines, at non-zero potential, within the spheres	**B1**
	magnitude of potential greater at surface of sphere A than at surface of sphere B	**B1**
	concave curve between A and B, with a minimum nearer to B	**B1**
	lines show *V* <u>positive</u> all the way from 0 to *D*	**B1**

Question	Answer	Marks
7(a)	$R / R_T = 2.4 / 1.8$ **or** at 4.0 °C, $R_T = 3.2\,\text{k}\Omega$	**C1**
	hence $R / 3.2 = 2.4 / 1.8$ $R = 4.3\,\text{k}\Omega$	**A1**
7(b)	$R_T = 3.37\,\text{k}\Omega$ **or** R_T is greater (than $3.2\,\text{k}\Omega$)	**B1**
	$V^+ > V^-$	**M1**
	hence output is +5.0 V	**A1**

Question	Answer	Marks
7(c)	correct LED symbol	**B1**
	two diodes shown connected, in parallel and with opposite polarities, between V_{OUT} and earth	**M1**
	diodes labelled to show correct polarities consistent with **(b)** (G pointing from V_{OUT} to earth and B pointing from earth to V_{OUT} if **(b)** correct)	**A1**

Question	Answer	Marks
8(a)	force per unit current	**B1**
	force per unit length (of wire)	**B1**
	current normal to (magnetic) field	**B1**
8(b)(i)	forces (on PQ and RS) are horizontal	**B1**
	(hence they create) no moment about the pivot	**B1**
	or	
	forces (on PQ and RS) are equal and opposite	**(B1)**
	(hence there is) no <u>net</u> force (on the two sections)	**(B1)**
8(b)(ii)	realisation of the need to apply moments	**C1**
	$BILx = mgy$ $B \times 2.7 \times 1.2 \times 10^{-2} \times 7.5 = 45 \times 10^{-6} \times 9.81 \times 8.8$	**C1**
	$B = 1.6 \times 10^{-2}$ T	**A1**

Question	Answer	Marks
9(a)	$0 \rightarrow t_1$ horizontal straight line at non-zero value of V_H **and** $t_3 \rightarrow t_4$ horizontal straight line at different non-zero V_H	**B1**
	$t_1 \rightarrow t_3$ straight diagonal line with negative gradient **and** graph line starts at $(0, V_0)$ and ends at $(t_4, -2V_0)$	**B1**
9(b)	$E = 0$ for $0 \rightarrow t_1$ **and** $t_3 \rightarrow t_4$	**B1**
	E is non-zero at all points between $t_1 \rightarrow t_3$	**M1**
	E has constant magnitude between $t_1 \rightarrow t_3$	**A1**

Question	Answer	Marks
10(a)	$V_0 = \sqrt{2} \times V_{r.m.s.} = \sqrt{2} \times 9.9$ (= 14 V) **and** $\omega = 2\pi f = 2\pi \times 50$ (= 314 rad s^{-1})	**C1**
	$V = 14 \sin 314t$	**A1**
10(b)	enables (resonating) nuclei to be located	**B1**
	resonant frequency depends on magnetic field strength	**B1**
	Any one from: • non-uniform field is (accurately) calibrated • (non-uniform) field may be varied to enable detection in different positions • unique (magnetic) field strength/frequency at each point	**B1**
10(c)	$I = I_0 \exp(-\mu x)$	**C1**
	$I = I_0 [\exp(-\mu x)_{bone} \times \exp(-\mu x)_{soft\ tissue}]$ $I = I_0 [\exp(-2.9 \times 0.40) \times \exp(-0.92 \times 1.4)]$	**C1**
	$I / I_0 = 0.0865$	**C1**
	ratio / dB = 10 lg 0.0865 = –11 dB	**A1**

Question	Answer	Marks
11(a)	discrete amount/quantum/packet of <u>energy</u>	**M1**
	of electromagnetic radiation	**A1**
11(b)	mostly dark/dark background	**B1**
	coloured lines	**B1**
11(c)(i)	6	**A1**
11(c)(ii)	**1.** maximum photon energy = 13.6 – 0.85 (= 12.75 eV)	**C1**
	maximum kinetic energy = (13.6 – 0.85) – 5.6 = 7.2 eV	**A1**
	2. energy = hc/λ	**C1**
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / [(13.6 - 0.85) \times 1.60 \times 10^{-19}]$	**C1**
	$= 9.8 \times 10^{-8}$ m	**A1**

Question	Answer	Marks
12(a)	fusion: two nuclei <u>combine</u> to form a (single) nucleus	**B1**
	fission: a (single) large nucleus <u>divides</u> to form (smaller) nuclei	**B1**
	Any one from: • fusion is initiated by (very) high temperatures • fission is initiated by neutron bombardment • resulting nuclei in fission are of similar size • (both processes) release energy • binding energy per nucleon increases • total binding energy increases • fission involves release of neutrons	**B1**
12(b)(i)	neutron	**B1**
12(b)(ii)	**1.** zero	**A1**
	2. $(4 \times 11.3290 \times 10^{-13}) - (2 \times 1.7813 \times 10^{-13}) - (3 \times 4.5285 \times 10^{-13})$	**C1**
	energy change $= 45.316 \times 10^{-13} - 17.148 \times 10^{-13}$ $= 2.82 \times 10^{-12}$ J	**A1**
12(b)(iii)	1.0 mol or N_A nuclei of each energy $= 2.817 \times 10^{-12} \times 6.02 \times 10^{23}$ $= 1.7 \times 10^{12}$ J	**A1**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 2020**

MARK SCHEME

Maximum Mark: 100

Published

Students did not sit exam papers in the June 2020 series due to the Covid-19 global pandemic.

This mark scheme is published to support teachers and students and should be read together with the question paper. It shows the requirements of the exam. The answer column of the mark scheme shows the proposed basis on which Examiners would award marks for this exam. Where appropriate, this column also provides the most likely acceptable alternative responses expected from students. Examiners usually review the mark scheme after they have seen student responses and update the mark scheme if appropriate. In the June series, Examiners were unable to consider the acceptability of alternative responses, as there were no student responses to consider.

Mark schemes should usually be read together with the Principal Examiner Report for Teachers. However, because students did not sit exam papers, there is no Principal Examiner Report for Teachers for the June 2020 series.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the June 2020 series for most Cambridge IGCSE™ and Cambridge International A & AS Level components, and some Cambridge O Level components.

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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- the standard of response required by a candidate as exemplified by the standardisation scripts.

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- 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.

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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	<u>'List rule' guidance</u> 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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

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. Within 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)	work done per unit mass	**B1**
	(work done to) move mass from infinity (to the point)	**B1**
1(b)	curve from r to $4r$, with gradient of decreasing magnitude and starting at (r, $\pm\phi$)	**B1**
	line passing through ($2r$, $\pm0.5\phi$) and ($4r$, $\pm0.25\phi$)	**B1**
	line showing potential is negative throughout	**B1**
1(c)(i)	gravitational potential energy = (–) GMm / R	**C1**
	change = $(6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 3.4 \times 10^{3}) / (6.4 \times 10^{6}) \times [1/3 - 1/4]$	**C1**
	= 1.8×10^{10} J	**A1**
1(c)(ii)	rock loses potential energy	**B1**
	(so) kinetic energy increases so speed increases	**B1**
	or	
	force is attractive	**(B1)**
	moves towards planet so speeds up	**(B1)**

Question	Answer	Marks
2(a)	ρ: Nm / V	B1
	⅓: molecules move in three dimensions (not one) so ⅓ in any (one) direction	B1
	$<c^2>$: molecules have different speeds so take average	M1
	of (speed)^2	A1
2(b)	$pV = NkT$	C1
	$N = (3.0 \times 10^5 \times 6.0 \times 10^{-3}) / (1.38 \times 10^{-23} \times 290)$	C1
	$= 4.5 \times 10^{23}$	C1
	mass $= 20.7 / (4.5 \times 10^{23})$ $= 4.6 \times 10^{-23}$ g	A1

Question	Answer	Marks
3(a)	(little/no volume change so) little/no external work done	B1
	thermal energy supplied to provide latent heat	M1
	internal energy increases	A1
3(b)	(rapid) increase in volume	B1
	gas does work against the atmosphere	M1
	internal energy decreases	A1

Question	Answer	Marks
4(a)	($\omega = 2\pi / T$ and T = 2.2 s so) $\omega = 2\pi / 2.2 = 2.9\ \text{rad s}^{-1}$	A1
4(b)(i)	$\omega^2 = g / R$	C1
	$R = 9.81 / 2.86^2$ $= 1.2\ \text{m}$	A1
4(b)(ii)	$v_0 = \omega x_0$	C1
	$= 2.9 \times 3.0 \times 10^{-2}$ $= 0.087\ \text{m s}^{-1}$	A1
4(c)	smooth wave starting at 3.0 cm when $t = 0$	B1
	positions of peaks and troughs show same period (or slightly longer)	B1
	each peak and trough at lower amplitude than the previous one	B1

Question	Answer	Marks
5(a)	pulses of ultrasound	**B1**
	ultrasound incident on quartz crystal	**B1**
	waves make crystal oscillate	**B1**
	oscillations (of crystal) generates an e.m.f. (across the crystal)	**B1**
5(b)	specific acoustic impedances of air and skin are very different	**B1**
	intensity reflection coefficient depends on difference between acoustic impedance	**B1**
	most ultrasound reflected so little transmission	**B1**

Question	Answer	Marks
6(a)	• greater bandwidth • less noise • less attenuation **or** fewer repeaters • less crosslinking **or** greater security *Any three points, 1 mark each*	**B3**
6(b)(i)	ratio / dB = 10 lg(P_1 / P_2)	**C1**
	21 = 10 lg [(6.3×10^{-17}) / P] P = 5.0×10^{-19} W	**A1**
6(b)(ii)	attenuation per unit length = (1 / 4.5×10^3) × 10 lg [(9.8×10^{-3}) / (6.3×10^{-17})]	**C1**
	= 0.032 dB km^{-1}	**A1**

Question	Answer	Marks
7(a)	force per unit charge	**M1**
	(force on) positive charge	**A1**
7(b)(i)	no electric field inside a conductor	**B1**
	$R = 4.5\,\text{cm}$	**A1**
7(b)(ii)	$E = Q / (4\pi\varepsilon_0 x^2)$	**C1**
	clear correct read-off of a pair of values of E and x	**C1**
	e.g. $Q = 18 \times 10^5 \times 4\pi \times 8.85 \times 10^{-12} \times (4.5 \times 10^{-2})^2$ $= 4.0 \times 10^{-7}\,\text{C}$ **or** $4.1 \times 10^{-7}\,\text{C}$	**A1**
7(c)	At 8.0 cm, $E = 5.75 \times 10^5\,\text{V m}^{-1}$	**C1**
	$F = Eq$ **and** $a = F / m$	**C1**
	$F = (5.75 \times 10^5 \times 2 \times 1.6 \times 10^{-19}) / (4 \times 1.66 \times 10^{-27})$ $= 2.8 \times 10^{13}\,\text{m s}^{-2}$	**A1**

Question	Answer	Marks
8(a)(i)	constant gain for all frequencies	**B1**
8(a)(ii)	unchanged	**B1**
8(b)(i)	(open loop) gain of op-amp is infinite	**B1**
	feedback loop ensures $V^{+} \approx V^{-}$ **or** any difference between V^{+} and V^{-} results in saturated output	**B1**
	non-inverting input is 0 V so inverting input also at 0 V	**B1**
8(b)(ii)	input = $(40 \times 1.5) / (40 + 110)$	**C1**
	= 0.40 V	**A1**
8(b)(iii)	gain = (–) (100 + 230) / 150 **or** feedback current = $0.40 / (150 \times 10^{3})$ (A)	**C1**
	p.d. = [(100 + 230) / 150] × 0.40 = 0.88 V	**A1**
8(c)	(magnitude of) gain decreases	**M1**
	voltmeter reading decreases	**A1**

Question	Answer	Marks
9(a)(i)	force is downwards/down the page **or** current is (right) to left	**B1**
	by left-hand rule, field is into plane of paper	**B1**
9(a)(ii)	magnetic force provides the centripetal force	**C1**
	$Bqv = mv^2 / r$	**C1**
	$v = Bqr / m$ $= (8.0 \times 10^{-4} \times 1.60 \times 10^{-19} \times 6.4 \times 10^{-2}) / (9.11 \times 10^{-31})$ $= 9.0 \times 10^{6}\ \text{m s}^{-1}$	**A1**
9(b)(i)	arrow showing field direction down the page	**B1**
9(b)(ii)	$Bqv = Eq$ **or** $v = E / B$	**C1**
	$E = 9.0 \times 10^{6} \times 8.0 \times 10^{-4}$ $= 7.2 \times 10^{3}\ \text{N C}^{-1}$	**A1**
9(c)	straight line/undeviated	**B1**
	condition for no deflection depends only on *v* **or** condition for no deflection does not depend on *m* or *q*	**B1**

Question	Answer	Marks
10(a)	(induced) electromotive force is proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
10(b)(i)	to change magnitude of potential difference	**B1**
10(b)(ii)	magnitude of e.m.f. varies as rate of change of flux changes	**B1**
	direction of e.m.f. changes when direction of change of flux reverses/when flux changes from increasing to decreasing	**B1**
	flux is continuously increasing and decreasing, so polarity of e.m.f. is continuously switching	**B1**
10(b)(iii)	to reduce energy/power losses **or** to reduce eddy currents	**B1**

Question	Answer	Marks
11(a)	conduction band and valence band overlap	B1
	number (density) of charge carriers does not vary	B1
	increase in temperature gives rise to <u>increased</u> lattice vibrations	B1
	(lattice) vibrations hinder movement of charge carriers so resistance increases	B1
11(b)	$mv = h / \lambda$	C1
	$v = (6.63 \times 10^{-34}) / [(2.6 \times 10^{-11}) \times (9.11 \times 10^{-31})]$ $(= 2.80 \times 10^{7}\ \text{m s}^{-1})$	C1
	$qV = ½mv^2$	C1
	$V = [9.11 \times 10^{-31} \times (2.80 \times 10^{7})^2] / [2 \times 1.60 \times 10^{-19}]$ $= 2.2 \times 10^{3}\ \text{V}$	A1

Question	Answer	Marks
12(a)	difference between mass of nucleus and mass of (constituent) nucleons	**M1**
	where nucleons are separated to infinity	**A1**
12(b)(i)	$E = mc^2$	**C1**
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 / (1.60 \times 10^{-13}) = 934$ MeV	**A1**
12(b)(ii)	mass defect = $2 \times (1.007276 + 1.008665) - 4.001506$ (= 0.030376)	**B1**
	binding energy per nucleon = $(0.030376 \times 934) / 4 = 7.09$ MeV	**A1**
12(c)	binding energy per nucleon is much greater	**M1**
	so would require a large amount of energy to separate the nucleons in helium	**A1**
	or	
	amount of energy released in forming hydrogen isotopes	**(M1)**
	is less than energy required to break apart helium nucleus	**(A1)**

Cambridge Assessment International Education

Cambridge International AS & A Level

PHYSICS **9702/42**

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

MARK SCHEME

Maximum Mark: 40

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.

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.

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. Within 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)	(gravitational) force per unit mass	**B1**
1(b)(i)	$g = GM / r^2$	**C1**
	$= (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (3.39 \times 10^6)^2$ $= 3.73\ \text{N kg}^{-1}$	**A1**
1(b)(ii)	$a = r\omega^2$ **and** $\omega = 2\pi / T$ **or** $a = v^2 / r$ **and** $v = 2\pi r / T$	**C1**
	$a = 3.39 \times 10^6 \times (2\pi / (24.6 \times 3600))^2$ $= 0.0171\ \text{m s}^{-2}$	**A1**
1(b)(iii)	force per unit mass $= 3.73 – 0.0171$ $= 3.71\ \text{N kg}^{-1}$	**A1**

Question	Answer	Marks
2(a)	$pV = nRT$	**C1**
	$pV = nRT$ **and** $N = nN_A$ **or** $pV = NkT$	**C1**
	$3.1 \times 10^{-3} \times 8.5 \times 10^5 = (N \times 290 \times 8.31) / (6.02 \times 10^{23})$ so $N = 6.6 \times 10^{23}$ **or** $3.1 \times 10^{-3} \times 8.5 \times 10^5 = N \times 1.38 \times 10^{-23} \times 290$ so $N = 6.6 \times 10^{23}$	**A1**
2(b)(i)	$(3.1 \times 10^{-3} \times 8.5 \times 10^5) / 290 = (6.3 \times 10^{-3} \times 2.7 \times 10^5) / T$ so $T = 190\,\text{K}$ **or** $6.3 \times 10^{-3} \times 2.7 \times 10^5 = 6.6 \times 10^{23} \times 1.38 \times 10^{-23} \times T$ so $T = 190\,\text{K}$	**A1**
2(b)(ii)	$\Delta U = 3/2 \times k \times \Delta T \times N$	**C1**
	$= 3/2 \times 1.38 \times 10^{-23} \times (190 - 290) \times 6.6 \times 10^{23}$	**C1**
	$= -1400\,\text{J}$	**A1**
2(c)	$\Delta U = q + w$	**M1**
	$q = 0$ so $\Delta U = w$	**A1**

Question	Answer	Marks
3(a)	acceleration in opposite direction to displacement shown by – sign	**B1**
	g / L is constant	**M1**
	(so) acceleration is (directly) proportional to displacement	**A1**
3(b)	$\omega^2 = g / L$	**C1**
	$\omega = 2\pi / T$ **or** $\omega = 2\pi f$ **and** $f = 1 / T$	**C1**
	$(2\pi / T)^2 = 9.81 / 0.18$ $T = 0.85$ s	**A1**
3(c)	energy $\propto x_0^2$	**C1**
	(after 3 cycles,) amplitude $= (0.94)^3 x_0$ $= 0.83 x_0$	**C1**
	ratio final energy / initial energy $= 0.83^2$ $= 0.69$	**A1**

Question	Answer	Marks
4(a)(i)	frequency (modulation)	**B1**
4(a)(ii)	**1.** zero	**B1**
	2. frequency (of 1.2 MHz) varies by ±50 kHz	**B1**
	frequency varies (by ±50 kHz) at a rate of 8000 times per second	**B1**
4(b)(i)	wavelength $= (3.00 \times 10^8) / (240 \times 10^3)$	**C1**
	(= 1250 m) = 1.25 km	**A1**
4(b)(ii)	bandwidth = 30 kHz	**A1**
4(b)(iii)	frequency = 15 kHz	**A1**

Question	Answer	Marks
5(a)	from x = 0 to x = r: horizontal line at V = 1.0V_0	**B1**
	from x = r to x = 3r: curve with negative gradient of decreasing magnitude starting at (r, 1.0V_0)	**B1**
	line passing through (2r, ½V_0) and (3r, ⅓V_0)	**B1**
5(b)	line with negative gradient from λ = ⅓λ_0 to λ = λ_0	**B1**
	line passing through (λ_0, 0)	**B1**
	curve with negative gradient of decreasing magnitude passing through (½λ_0, E_{MAX}) and (⅓λ_0, 2E_{MAX})	**B1**
5(c)	1.0$T_{½}$ shown at ½N_0 **and** 2.0$T_{½}$ shown at ¼N_0	**B1**
	line starting at (0, 0) and reaching (T, N_0–N)	**B1**
	line starting at (0, 0) and reaching original curve at (1.0$T_{½}$, ½N_0)	**B1**

Question	Answer	Marks
6(a)	potential difference applied between the plates	**M1**
	causes charge separation (between the plates) **or** causes energy to be stored (between the plates)	**A1**
6(b)(i)	$I = Q / t$	**M1**
	clear substitution of $Q = CV$ and $f = 1 / t$, leading to $I = fCV$	**A1**
6(b)(ii)	$2.5 \times 10^{-6} = 50 \times C \times 180$	**C1**
	C = 280 pF	**A1**
6(c)	(total) capacitance increases	**B1**
	greater charge (for each cycle/discharge) so greater (average) current **or** V and f are constant so (average) current increases **or** I is (directly) proportional to C so (average) current increases	**B1**

Question	Answer	Marks
7(a)(i)	no current enters/leaves the input	**B1**
7(a)(ii)	gain is the same for all frequencies	**B1**
7(b)(i)	$V_{IN} = 1.5 \times 400 / (400 + 1100) = 0.40\ V$ **or** $V_{IN} = 1.5 - (1.5 \times 1100 / 1500) = 0.40\ V$ **or** $(1.5 - V_{IN}) / 1100 = V_{IN} / 400$ so $V_{IN} = 0.40\ V$	**A1**
7(b)(ii)	gain = (–) R_f / R_i	**C1**
	$V_{OUT} / 0.40 = (360 + 100) / 96$	**C1**
	$V_{OUT} = 1.9\ V$	**A1**
7(b)(iii)	resistance <u>of thermistor</u> decreases	**B1**
	(magnitude of) gain decreases so reading decreases	**B1**
7(b)(iv)	(at gain 12.5) V_{OUT} is 5.0 V, so (above gain 12.5) output becomes saturated	**B1**

Question	Answer	Marks
8(a)	• force per unit length • force per unit current • length/current perpendicular to field *1 mark for any two points, 2 marks for all three points*	**B2**
8(b)	change in potential energy = change in kinetic energy **or** $qV = \frac{1}{2}mv^2$	**B1**
	$v = \sqrt{(2qV / m)}$	**A1**
8(c)(i)	magnetic force = centripetal force **or** $Bqv = mv^2 / r$	**M1**
	clear substitution of expression for *v* and correct algebra leading to $q / m = 2V / B^2r^2$	**A1**
8(c)(ii)	$q / m = (2 \times 230) / [(0.38 \times 10^{-3})^2 \times 0.14^2]$	**C1**
	$= 1.6 \times 10^{11}$ C kg^{-1}	**A1**
8(c)(iii)	(for α-particle,) q / m is (much) smaller	**B1**
	r would be <u>much</u> larger	**B1**

Question	Answer	Marks
9(a)	(particle is) stationary/not moving	**B1**
	(particle is) moving parallel to the (magnetic) field	**B1**
9(b)	magnetic field around each coil is circular **or** each coil is normal to magnetic field due to adjacent coils	**B1**
	current in coil interacts with (magnetic) field to exert force (on coil)	**B1**
	force is normal to both coil and magnetic field **or** force parallel to axis (of coil)	**B1**
	forces between coils are attractive so spring contracts	**B1**
9(c)	(oscillating) coils cut magnetic flux **or** as separation of coils changes, magnetic flux changes	**B1**
	cutting flux causes induced e.m.f. in coils	**B1**
	<u>changing</u> (induced) e.m.f. causes changing current (in coil)	**B1**

Question	Answer	Marks
10(a)	the steady current **or** the direct current	**M1**
	that produces the same heating effect (as the alternating current)	**A1**
10(b)(i)	peak current = 2.6 A **and** r.m.s. current = 1.8 A	**A1**
10(b)(ii)	peak current = 2.0 A **and** r.m.s. current = 2.0 A	**A1**
10(c)(i)	$k = 2\pi f$	**C1**
	$= 2\pi \times 50$ $= 310\ \text{rad s}^{-1}$	**A1**
10(c)(ii)	power = V_{RMS}^2 / R **or** power = $V_0^2 / 2R$	**C1**
	$R = (240 / \sqrt{2})^2 / 3200$ **or** $R = 240^2 / (2 \times 3200)$ $R = 9.0\ \Omega$	**A1**

Question	Answer	Marks
11(a)	to produce a 3-dimensional image of structure/body	**B1**
11(b)	X-rays (are used)	**B1**
	scanning in sections	**B1**
	scanning from many angles	**B1**
	image of each section is 2-dimensional	**B1**
	scanning repeated for many sections **or** images of many sections combined together	**B1**

Question	Answer	Marks
12(a)	quantum of energy	**M1**
	of electromagnetic radiation	**A1**
12(b)(i)	energy = hc / λ **or** energy = hf **and** $f = c / \lambda$	**C1**
	$0.57 \times 10^6 \times 1.60 \times 10^{-19} = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$ $\lambda = 2.2 \times 10^{-12}$ m	**A1**

Question	Answer	Marks
12(b)(ii)	$p = h / \lambda$	**C1**
	$= (6.63 \times 10^{-34}) / (2.2 \times 10^{-12})$ $= 3.0 \times 10^{-22}$ N s	**A1**
	or	
	$p = E / c$	**(C1)**
	$= (0.57 \times 10^{6} \times 1.60 \times 10^{-19}) / (3.00 \times 10^{8})$ $= 3.0 \times 10^{-22}$ N s	**(A1)**
12(c)(i)	mass (of Sm-157 nucleus) = $157 \times 1.66 \times 10^{-27}$ **or** mass (of Sm-157 nucleus) = $0.157 / (6.02 \times 10^{23})$	**C1**
	recoil speed = $(3.00 \times 10^{-22}) / (157 \times 1.66 \times 10^{-27})$ $= 1.2 \times 10^{3}$ m s^{-1}	**A1**
12(c)(ii)	$(1.2 \times)\ 10^{3}$ m s^{-1} is <u>much</u> less than $(3.0 \times)\ 10^{8}$ m s^{-1}	**B1**