



Cambridge International AS & A Level

PHYSICS

9702/41

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.

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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 <i>n</i> responses (e.g. State two reasons ...): • The response should be read as continuous prose, even when numbered answer spaces are provided • Any response marked <i>ignore</i> in the mark scheme should not count towards <i>n</i> • Incorrect responses should not be awarded credit but will still count towards <i>n</i> • 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 <i>n</i> 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. <u>Within</u> a section of a numerical question, ECF can be given after AE, TE and POT errors, but not after XP.
AE	Indicates an arithmetic error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
POT	Indicates a power of ten error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
TE	Indicates incorrect transcription of the correct data from the question, a graph, data sheet or a previous answer. For example, the value of 1.6×10^{-19} has been written down as 6.1×10^{-19} or 1.6×10^{19} . Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
SF	Indicates that the correct answer is seen in the working but the final answer is incorrect as it is expressed to too few significant figures.
BOD	Indicates that a mark is awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done ('benefit of doubt').
CON	Indicates that a response is contradictory.
I	Indicates parts of a response that have been seen but disregarded as irrelevant.
M0	Indicates where an A category mark has not been awarded due to the M category mark upon which it depends not having previously been awarded.

^	Indicates where more is needed for a mark to be awarded (what is written is not wrong, but not enough). May also be used to annotate a response space that has been left completely blank.
SEEN	Indicates that a page has been seen.

Question	Answer	Marks
1(a)	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 = $r\theta$ $d = 1.5 \times 10^{17} \times 1.2 \times 10^{-5} = 1.8 \times 10^{12} \text{ m}$	A1
1(c)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (44.2 \times 365 \times 24 \times 3600)$	A1
	$= 4.5 \times 10^{-9} \text{ rad s}^{-1}$	
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
	$M_1 = 1.1 \times 10^{30} \text{ kg}$	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 m s^{-1}	A1
3(a)(iv)	$v = \omega (x_0^2 - x^2)^{1/2}$ = $2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{1/2}$	C1
	= 12 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
	$0.35 = e^{-0.046\mu}$ $\mu = 23 \text{ m}^{-1}$	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 = $Q / 4\pi\epsilon_0 x^2$	C1
	$E = Q / 36\pi\epsilon_0 R^2$	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
	$13 = 10 \lg [P / (1.0 \times 10^{-3})]$ and so $P = 20 \text{ mW}$	A1
6(c)	$45 \times 0.18 = 10 \lg (20 / P)$	C1
	$P = 3.1 \text{ mW}$	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)	$\text{gain} = V_{\text{OUT}} / V_{\text{IN}}$ $= 2.6 / 0.084$ $= 31$	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
	$= 45 \times 10^{-3} \times \pi \times (1.8 \times 10^{-2})^2 \times 350 / 0.20 = 0.080 \text{ V}$	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 <i>Any four points, 1 mark each</i>	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
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$	A1
	$= 8.2 \times 10^{-14} \text{ J}$	
11(a)(ii)	$p = h / \lambda$ and $E = hc / \lambda$ or $E = pc$	C1
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$	A1
	$= 2.7 \times 10^{-22} \text{ N s}$	
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 $\lambda = \ln 2 / t_{1/2}$	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 $(0, 3.6 \times 10^5)$ and passing through $(1.4, 1.8 \times 10^5)$ and $(2.0, 1.3 \times 10^5)$	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



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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 $(2r, \pm 0.5\phi)$ and $(4r, \pm 0.25\phi)$	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
	= $1.8 \times 10^{10} \text{ J}$	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)	$\rho: Nm / V$	B1
	$\frac{1}{3}$: molecules move in three dimensions (not one) so $\frac{1}{3}$ in any (one) direction	B1
	$\langle c^2 \rangle$: 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 = $20.7 / (4.5 \times 10^{23})$ $= 4.6 \times 10^{-23} \text{ g}$	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)	$(\omega = 2\pi / T \text{ and } T = 2.2 \text{ s so})$ $\omega = 2\pi / 2.2 = 2.9 \text{ rad s}^{-1}$	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 <i>Any three points, 1 mark each</i>	B3
6(b)(i)	ratio / dB = $10 \lg(P_1 / P_2)$	C1
	$21 = 10 \lg [(6.3 \times 10^{-17}) / P]$	A1
	$P = 5.0 \times 10^{-19} \text{ W}$	
6(b)(ii)	attenuation per unit length = $(1 / 4.5 \times 10^3) \times 10 \lg [(9.8 \times 10^{-3}) / (6.3 \times 10^{-17})]$	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)	$E = Q / (4\pi\epsilon_0 x^2)$	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. = $[(100 + 230) / 150] \times 0.40$ = 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
	$qV = \frac{1}{2}mv^2$	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
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 / (1.60 \times 10^{-13}) = 934 \text{ MeV}$	A1
12(b)(ii)	mass defect = $2 \times (1.007276 + 1.008665) - 4.001506$ (= 0.030376)	B1
	binding energy per nucleon = $(0.030376 \times 934) / 4 = 7.09 \text{ MeV}$	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 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.

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 <i>n</i> responses (e.g. State two reasons ...): • The response should be read as continuous prose, even when numbered answer spaces are provided • Any response marked <i>ignore</i> in the mark scheme should not count towards <i>n</i> • Incorrect responses should not be awarded credit but will still count towards <i>n</i> • 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 <i>n</i> 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. <u>Within</u> a section of a numerical question, ECF can be given after AE, TE and POT errors, but not after XP.
AE	Indicates an arithmetic error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
POT	Indicates a power of ten error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
TE	Indicates incorrect transcription of the correct data from the question, a graph, data sheet or a previous answer. For example, the value of 1.6×10^{-19} has been written down as 6.1×10^{-19} or 1.6×10^{19} . Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
SF	Indicates that the correct answer is seen in the working but the final answer is incorrect as it is expressed to too few significant figures.
BOD	Indicates that a mark is awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done ('benefit of doubt').
CON	Indicates that a response is contradictory.
I	Indicates parts of a response that have been seen but disregarded as irrelevant.
M0	Indicates where an A category mark has not been awarded due to the M category mark upon which it depends not having previously been awarded.

^	Indicates where more is needed for a mark to be awarded (what is written is not wrong, but not enough). May also be used to annotate a response space that has been left completely blank.
SEEN	Indicates that a page has been seen.

Question	Answer	Marks
1(a)	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 = $r\theta$ $d = 1.5 \times 10^{17} \times 1.2 \times 10^{-5} = 1.8 \times 10^{12} \text{ m}$	A1
1(c)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (44.2 \times 365 \times 24 \times 3600)$	A1
	$= 4.5 \times 10^{-9} \text{ rad s}^{-1}$	
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
	$M_1 = 1.1 \times 10^{30} \text{ kg}$	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 m s ⁻¹	A1
3(a)(iv)	$v = \omega (x_0^2 - x^2)^{1/2}$ = $2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{1/2}$	C1
	= 12 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
	$= 2500 \text{ N}$	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
	$0.35 = e^{-0.046\mu}$ $\mu = 23 \text{ m}^{-1}$	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 = $Q / 4\pi\epsilon_0 x^2$	C1
	$E = Q / 36\pi\epsilon_0 R^2$	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
	$13 = 10 \lg [P / (1.0 \times 10^{-3})]$ and so $P = 20 \text{ mW}$	A1
6(c)	$45 \times 0.18 = 10 \lg (20 / P)$	C1
	$P = 3.1 \text{ mW}$	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)	$\text{gain} = V_{\text{OUT}} / V_{\text{IN}}$ $= 2.6 / 0.084$ $= 31$	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
	$= 45 \times 10^{-3} \times \pi \times (1.8 \times 10^{-2})^2 \times 350 / 0.20 = 0.080 \text{ V}$	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 <i>Any four points, 1 mark each</i>	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
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$	A1
	$= 8.2 \times 10^{-14} \text{ J}$	
11(a)(ii)	$p = h / \lambda$ and $E = hc / \lambda$ or $E = pc$	C1
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$	A1
	$= 2.7 \times 10^{-22} \text{ N s}$	
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 $\lambda = \ln 2 / t_{1/2}$	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 $(0, 3.6 \times 10^5)$ and passing through $(1.4, 1.8 \times 10^5)$ and $(2.0, 1.3 \times 10^5)$	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