



Cambridge International AS & A Level

PHYSICS

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

Abbreviations

/	Alternative and acceptable answers for the same marking point.
()	Bracketed content indicates words which do not need to be explicitly seen to gain credit but which indicate the context for an answer. The context does not need to be seen but if a context is given that is incorrect then the mark should not be awarded.
—	Underlined content must be present in answer to award the mark. This means either the exact word or another word that has the same technical meaning.

Mark categories

B marks	These are <u>independent</u> marks, which do not depend on other marks. For a B mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer.
M marks	These are <u>method</u> marks upon which A marks later depend. For an M mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer. If a candidate is not awarded an M mark, then the later A mark cannot be awarded either.
C marks	These are <u>compensatory</u> marks which can be awarded even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known them. For example, if an equation carries a C mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the C mark is awarded. If a correct answer is given to a numerical question, all of the preceding C marks are awarded automatically. It is only necessary to consider each of the C marks in turn when the numerical answer is not correct.
A marks	These are <u>answer</u> marks. They may depend on an M mark or allow a C mark to be awarded by implication.

Annotations

✓	Indicates the point at which a mark has been awarded.
X	Indicates an incorrect answer or a point at which a decision is made not to award a mark.
XP	Indicates a physically incorrect equation ('incorrect physics'). No credit is given for substitution, or subsequent arithmetic, in a physically incorrect equation.
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.

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^	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)	$GMm/r^2 = m\omega^2$ 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
	$r = 6.9 \times 10^6 \text{ m}$	A1
1(c)(i)	$r^3\omega^2 = \text{constant}$ or $r^3/T^2 = \text{constant}$	C1
	$r^3 / (6.9 \times 10^6)^3 = (150/94)^2$ so $r = 9.4 \times 10^6 \text{ m}$	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 $r = 9.4 \times 10^6 \text{ m}$	(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
	$= 1.9 \times 10^{10} \text{ J}$	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
	$= -64 \text{ J}$	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
	$f = 2.8 \text{ Hz}$	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
	$73 = 10 \lg (P_T / P_R)$	C1
	$73 = 10 \lg (P_T x^2 / 0.082 P_T)$ or $x^2 / 0.082 = 10^{7.3}$	
	$x = 1300$ 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 <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
	$C = 530 \text{ pF}$	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 = $2.4 \mu\text{A}$	B1

Question	Answer	Marks
8(a)	$V^+ = 3.0 \times 3.0 / (2.5 + 3.0)$	C1
	$= 1.6 \text{ V}$	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, $V^- = 1.7 \text{ V}$ or for all temperatures above 0 °C, resistance of thermistor < 4.2 k Ω	B1
	V^- always greater than V^+ (so no switching)	B1
8(d)	(at 20 °C,) $R_T = 1.8 \text{ k}\Omega$	C1
	$2.5 / 3.0 = 1.8 / R$ or $[R / (R + 1.8)] \times 3.0 = 1.6$	C1
	$R = 2.2 \text{ k}\Omega$	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)	<ul style="list-style-type: none"> frequency determines energy of photon intensity determines number of photons (per unit time) intensity does not determine energy of a photon <i>Any two points, 1 mark each</i>	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
	$(= 7.96 \times 10^{-19} \text{ J})$ $= 5.0 \text{ eV}$	A1
12(b)(ii)	$E_{\text{MAX}} = \text{photon energy} - \text{work function}$	C1
	work function = $5.0 - 1.4$ $= 3.6 \text{ eV}$	A1