
PHYSICS

9702/41

Paper 4 A Level Structured Questions

May/June 2019

MARK SCHEME

Maximum Mark: 100

Published

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Cambridge International is publishing the mark schemes for the May/June 2019 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 **15** printed pages.



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PUBLISHED**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
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$	A1
	so $v = 3.7 \times 10^3 \text{ m s}^{-1}$	
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 $\Delta E_p = 8.3 \times 10^9 \text{ J}$	A1
	or	
	$\phi = (-)GM / x$ and potential energy = $m\phi$	(C1)
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1 / (3.64 \times 10^6)) - (1 / (5.00 \times 10^7))]$ $(= 1.27 \times 10^7 \text{ J kg}^{-1})$	(M1)
	$\Delta E_p = 1.27 \times 10^7 \times 650$ $= 8.3 \times 10^9 \text{ J}$	(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
	$= 0.028 \text{ mol}$	A1
2(a)(ii)	$V \propto T$ or $T = pV / nR$ with value of n from (i)	C1
	$T = (140 / 210) \times 270$ or $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$	A1
	$= 180 \text{ K}$	
2(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	C1
	$= 21 \text{ J}$	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)
	$\Delta U = (-)32 \text{ J}$	A1

Question	Answer	Marks
3(a)(i)	amplitude = 0.020 m	A1
3(a)(ii)	$T = 0.60 \text{ s}$	C1
	$f = 1 / T$ $= 1.7 \text{ Hz}$	A1
3(a)(iii)	$a = (-)\omega^2 x$ and $[\omega = 2\pi f \text{ or } \omega = 2\pi / T]$	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

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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)	0101	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)	$E = Q / (4\pi\epsilon_0 x^2)$	C1
	at $x = 10 \text{ cm}$, $E_A = E_B$	C1
	$Q_A / 10^2 = Q_B / 5^2$ $Q_A / Q_B = 4.0$	A1

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

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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
	= $1.2 \times 10^{-3} \text{ V}$	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)	$V_{\text{MAX}} = 15 \text{ V}$	A1
10(b)	$210 = 2\pi / T$	C1
	$T = 0.0299 \text{ s}$	C1
	$(t_2 - t_1) = 0.060 \text{ s}$	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 / λ	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 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
	$\text{force} = 1.74 \times 10^{-27} \times 7.6 \times 10^{14}$ $= 1.3 \times 10^{-12} \text{ N}$	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 = $5.60 \times 10^{-3} \text{ u}$	A1
	2. energy = $(\Delta)mc^2$	C1
	$= 5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $(= 8.36 \times 10^{-13} \text{ J})$	C1
	$= 0.84 \text{ pJ}$	A1
12(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	B1
	energy of γ -ray photon	B1

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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 = $1.5 \times 10^{-2} \times 9.3 \times 10^{-10}$ = 1.4×10^{-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

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Question	Answer	Marks								
2(a)(i)	1. energy transfer <u>to</u> the system by heating	B1								
	2. (external) work done <u>on</u> the system	B1								
2(a)(ii)	<u>decrease</u> 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: <table border="1" data-bbox="322 1145 739 1343"> <tr> <td>0</td><td>480</td><td>480</td></tr> <tr> <td>-1100</td><td>0</td><td>-1100</td></tr> <tr> <td>860</td><td>-240</td><td>620</td></tr> </table>)	0	480	480	-1100	0	-1100	860	-240	620
0	480	480								
-1100	0	-1100								
860	-240	620								

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
	$= 2\pi / 0.40$	A1
	$= 16 \text{ rad s}^{-1}$	
3(b)(ii)	$v_0 = \omega x_0$	C1
	$= 15.7 \times 2.5 \times 10^{-2}$	A1
	$= 0.39 \text{ m s}^{-1}$	
	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 $\pm 0.15 \text{ m s}^{-1}$)	(A1)
3(b)(iii)	$a_0 = \omega^2 x_0$	C1
	$a_0 = (15.7^2 \times 2.5 \times 10^{-2})$	A1
	$= 6.2 \text{ m s}^{-2}$	
	or	
	$a_0 = \omega v_0$	(C1)
	$a_0 = 15.7 \times 0.39$	(A1)
	$= 6.2 \text{ m s}^{-2}$	

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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
	$x = 0.047 \text{ m}$	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 = $(1 / L) \times 10 \lg(P_2 / P_1)$ $= (1 / 52) \times 10 \lg [(2.5 \times 10^{-3}) / (7.8 \times 10^{-16})]$	C1
	$= 2.4 \text{ dB km}^{-1}$	A1
5(b)(ii)	gain / dB = $10 \lg(P_2 / P_1)$ $115 = 10 \lg [P / (7.8 \times 10^{-16})]$	C1
	$P = 2.5 \times 10^{-4} \text{ W}$	A1

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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

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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 k Ω	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

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Question	Answer	Marks
8(a)(i)	$v_N = 3.4 \times 10^7 \times \sin 30^\circ$ $= 1.7 \times 10^7 \text{ m s}^{-1}$	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

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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 <u>magnetic</u> 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 $\sqrt{2}$ factor: to peak applied e.m.f., giving $220 / \sqrt{2}$ or to peak output em.f., giving $37 / \sqrt{2}$	C1
	$V_{\text{r.m.s.}} = 26 \text{ V}$	A1

Question	Answer	Marks
11(a)	packet/quantum of <u>energy</u>	M1
	of electromagnetic radiation	A1
11(b)(i)	$E = hc / \lambda$	C1
	$1.18 \times 1.60 \times 10^{-13} = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$	A1
	$\lambda = 1.05 \times 10^{-12} \text{ m}$	
11(b)(ii)	$\lambda = h / p$ or $E = pc$	C1
	$p = (6.63 \times 10^{-34}) / (1.05 \times 10^{-12})$ or $p = (1.18 \times 1.60 \times 10^{-13}) / (3.00 \times 10^8)$	B1
	leading to $p = 6.3 \times 10^{-22} \text{ N s}$	
11(c)	$6.3 \times 10^{-22} = 60 \times 1.66 \times 10^{-27} \times v$	C1
	$v = 6.3 \times 10^3 \text{ m s}^{-1}$	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 = $140.911 - (57 \times 1.007) - (84 \times 1.009)$	C1
	= $140.911 - 142.155$	C1
	= $(-)1.244$ (u)	
	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)	$A = A_0 e^{-\lambda t}$ and $\ln 2 = \lambda t_{1/2}$	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

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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 **15** printed pages.



Cambridge Assessment
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PUBLISHED**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
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$	A1
	so $v = 3.7 \times 10^3 \text{ m s}^{-1}$	
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 $\Delta E_p = 8.3 \times 10^9 \text{ J}$	A1
	or	
	$\phi = (-)GM / x$ and potential energy = $m\phi$	(C1)
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1 / (3.64 \times 10^6)) - (1 / (5.00 \times 10^7))]$ (= $1.27 \times 10^7 \text{ J kg}^{-1}$)	(M1)
	$\Delta E_p = 1.27 \times 10^7 \times 650$ = $8.3 \times 10^9 \text{ J}$	(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
	$= 0.028 \text{ mol}$	A1
2(a)(ii)	$V \propto T$ or $T = pV / nR$ with value of n from (i)	C1
	$T = (140 / 210) \times 270$ or $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$	A1
	$= 180 \text{ K}$	
2(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	C1
	$= 21 \text{ J}$	A1

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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)
	$\Delta U = (-)32 \text{ J}$	A1

Question	Answer	Marks
3(a)(i)	amplitude = 0.020 m	A1
3(a)(ii)	$T = 0.60 \text{ s}$	C1
	$f = 1 / T$ $= 1.7 \text{ Hz}$	A1
3(a)(iii)	$a = (-)\omega^2 x$ and $[\omega = 2\pi f \text{ or } \omega = 2\pi / T]$	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

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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)	0101	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)	$E = Q / (4\pi\epsilon_0 x^2)$	C1
	at $x = 10 \text{ cm}$, $E_A = E_B$	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,) $V_{\text{OUT}} = 5 \text{ V}$	C1
	p.d. across R = $5 - 2.3$ $= 2.7 \text{ (V)}$	C1
	resistance = $2.7 / (30 \times 10^{-3})$ $= 90 \Omega$	A1
	or	
	$R_{\text{diode}} = 2.3 / 0.030 = 77 \Omega$ $R_{\text{total}} = 5.0 / 0.030 = 167 \Omega$	(C1)
	$R_{\text{resistor}} (= 167 - 77) = 90 \Omega$	(A1)
	or	
	$R_{\text{diode}} = 2.3 / 0.030 = 77 \Omega$ $77 / (R_{\text{resistor}} + 77) \times 5 = 2.3$	(C1)
	$R_{\text{resistor}} = 90 \Omega$	(A1)
	or	
	$R_{\text{diode}} = 2.3 / 0.030 = 77 \Omega$ $R_{\text{resistor}} = 77 \times (2.7 / 2.3)$	(C1)
	$R_{\text{resistor}} = 90 \Omega$	(A1)

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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
	= $1.2 \times 10^{-3} \text{ V}$	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)	$V_{\text{MAX}} = 15 \text{ V}$	A1
10(b)	$210 = 2\pi / T$	C1
	$T = 0.0299 \text{ s}$	C1
	$(t_2 - t_1) = 0.060 \text{ s}$	A1

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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 / λ	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 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
	$\text{force} = 1.74 \times 10^{-27} \times 7.6 \times 10^{14}$ $= 1.3 \times 10^{-12} \text{ N}$	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 = $5.60 \times 10^{-3} \text{ u}$	A1
	2. energy = $(\Delta)mc^2$	C1
	$= 5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $(= 8.36 \times 10^{-13} \text{ J})$	C1
	$= 0.84 \text{ pJ}$	A1
12(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	B1
	energy of γ -ray photon	B1