
PHYSICS

9702/41

Paper 4 A Level Structured Questions

October/November 2019

MARK SCHEME

Maximum Mark: 100

Published

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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.

PUBLISHED**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.

PUBLISHED

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
	$M = 6.0 \times 10^{24} \text{ kg}$	A1

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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)
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (273 + 23)$ $n = 4.49 \text{ (mol)}$ $N = nN_A$ $= 4.49 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.7 \times 10^{24}$	A1

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

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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

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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
	$f = 1.8\text{ Hz}$	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
	$32 = 10 \lg \{P_{\text{MIN}} / (7.6 \times 10^{-6})\}$	A1
	$P_{\text{MIN}} = 0.012 \text{ W}$	
5(b)(ii)	attenuation per unit length = $(1 / L) \times 10 \lg (P_1 / P_2)$	C1
	$6.3 = (1 / L) \times 10 \lg (2.6 / 0.012)$	
	$L = 3.7 \text{ km}$	A1

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Question	Answer	Marks
6(a)	$(E =) Q / 4\pi\epsilon_0 r^2$	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 $\times$ charge and force = mass $\times$ 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

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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)	$\text{gain} = 1 + R_F / R_{IN}$ $= 1 + (4000 / 800)$	C1
	$= 6.0$	A1
7(b)(ii)	$2.0 / V_{IN} = 6.0$ $V_{IN} = (+)0.33 \text{ V}$	A1
7(b)(iii)	5.0 V	A1
7(b)(iv)	$V = 5.0 - 2.2 (= 2.8 \text{ V})$	C1
	$R = V / I$ $= 2.8 / 0.020$ $= 140 \Omega$	A1

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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
	$= 4.0 \times 10^{-5} \text{ T}$	A1
8(b)(ii)	$F = BIL$ or $F/L = BI$	C1
	$F/L = 4.0 \times 10^{-5} \times 8.5$ $= 3.4 \times 10^{-4} \text{ N m}^{-1}$	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 <i>any two points, one mark each</i>	B2

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Question	Answer	Marks
10(a)(i)	lower right and upper left diodes circled	B1
10(a)(ii)	maximum = $7.0\sqrt{2}$ = 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

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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 / λ	C1
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (280 \times 10^{-9})$ $= 7.1 \times 10^{-19} \text{ J}$	A1
	2. electron energy = $(7.1 - 5.5) \times 10^{-19} \text{ J}$	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = (7.1 - 5.5) \times 10^{-19}$	C1
	$v = 5.9 \times 10^5 \text{ m s}^{-1}$	A1
11(b)(ii)	energy is required to bring electron to the surface	B1
11(c)	no change	B4
	increases	

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

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	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
	$M = 6.45 \times 10^{23} \text{ kg}$	A1

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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
	<u>causes</u> the (haphazard) motion of the smoke particles or <u>causes</u> 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)
	$n = 0.350 \text{ mol}$ or 0.349 mol	A1
2(b)(ii)	energy transfer = $(0.349 \text{ or } 0.35) \times 12.5 \times (310 - 290)$	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

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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

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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
	$T = 0.80 \text{ s}$, so $\omega = 2\pi / 0.80$ $\omega = 7.9 \text{ rad s}^{-1}$	A1
4(b)(ii)	$\omega^2 = 2k / M$	C1
	$7.9^2 = 2k / 1.2$ $k = 37 \text{ N m}^{-1}$	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/peak</u> is less sharp - peak at (slightly) lower angular frequency/peak moves to left any two points, one mark each	B2

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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

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Question	Answer	Marks
6(a)	period = $5.0 \mu\text{s}$, so frequency = $2.0 \times 10^5 \text{ Hz}$	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

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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)	<i>any one correct starting point from:</i> • (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 cm³ volume contains) 0.1 mol • (1 m³ 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
	$= 8.0 \times 10^{-7} \text{ V}$	A1

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Question	Answer	Marks
9(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity	B1
9(b)(i)	energy = $4.8 \times 1.60 \times 10^{-13}$ = 7.7×10^{-13} J	A1
9(b)(ii)	$E_P = Qq / 4\pi\epsilon_0 d$	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

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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
	$R_T = 2.2 \text{ (k}\Omega\text{)}$	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

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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

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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 $4.80 \times 10^{-3} \text{ m}^3$) 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

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- 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.

PUBLISHED**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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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
	$M = 6.0 \times 10^{24} \text{ kg}$	A1

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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)
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (273 + 23)$ $n = 4.49 \text{ (mol)}$ $N = nN_A$ $= 4.49 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.7 \times 10^{24}$	A1

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

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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

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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
	$f = 1.8 \text{ Hz}$	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
	$32 = 10 \lg \{P_{\text{MIN}} / (7.6 \times 10^{-6})\}$	A1
	$P_{\text{MIN}} = 0.012 \text{ W}$	
5(b)(ii)	attenuation per unit length = $(1 / L) \times 10 \lg (P_1 / P_2)$	C1
	$6.3 = (1 / L) \times 10 \lg (2.6 / 0.012)$	
	$L = 3.7 \text{ km}$	A1

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Question	Answer	Marks
6(a)	$(E =) Q / 4\pi\epsilon_0 r^2$	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 $\times$ charge and force = mass $\times$ 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

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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)	$2.0 / V_{IN} = 6.0$ $V_{IN} = (+)0.33 \text{ V}$	A1
7(b)(iii)	5.0 V	A1
7(b)(iv)	$V = 5.0 - 2.2 (= 2.8 \text{ V})$	C1
	$R = V / I$ = $2.8 / 0.020$ = 140Ω	A1

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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
	$= 4.0 \times 10^{-5} \text{ T}$	A1
8(b)(ii)	$F = BIL$ or $F/L = BI$	C1
	$F/L = 4.0 \times 10^{-5} \times 8.5$	A1
	$= 3.4 \times 10^{-4} \text{ N m}^{-1}$	
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

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Question	Answer	Marks
10(a)(i)	lower right and upper left diodes circled	B1
10(a)(ii)	maximum = $7.0\sqrt{2}$ = 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

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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 / λ	C1				
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (280 \times 10^{-9})$ $= 7.1 \times 10^{-19} \text{ J}$	A1				
	2. electron energy = $(7.1 - 5.5) \times 10^{-19} \text{ J}$	C1				
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = (7.1 - 5.5) \times 10^{-19}$	C1				
	$v = 5.9 \times 10^5 \text{ m s}^{-1}$	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>	no change	decreases	increases	decreases	B4
no change	decreases					
increases	decreases					

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