Oxford Cambridge and RSA Examinations

OCR
RECOGNISING ACHIEVEMENT

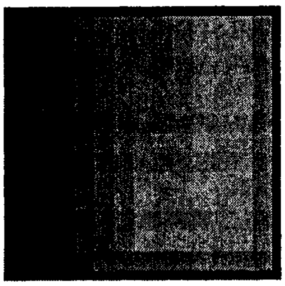
ADVANCED GCE
ADVANCED SUBSIDIARY GCE

A2 7888
AS 3888

PHYSICS B
(ADVANCING PHYSICS)

MARK SCHEME FOR THE UNITS
JUNE 2004

AS/A2



3888/7888/MS/04

Advanced Subsidiary GCE Physics B (Advancing Physics) 3888
June 2004 Assessment Session

Unit Threshold Marks

Unit		Maximum Mark	a	b	c	d	e	u
2860	Raw	90	64	56	49	42	35	0
	UMS	100	80	70	60	50	40	0
2861	Raw	90	59	51	44	37	30	0
	UMS	110	88	77	66	55	44	0
2862	Raw	120	97	85	73	62	51	0
	UMS	90	72	63	54	45	36	0

Specification Aggregation Results

Overall threshold marks in UMS (i.e. after conversion of raw marks to uniform marks)

	Maximum Mark	A	B	C	D	E	U
3888	300	240	210	180	150	120	0

The cumulative percentage of candidates awarded each grade was as follows:

	A	B	C	D	E	U	Total Number of Candidates
3888	24.0	43.7	62.3	79.6	91.0	100.0	6682

Advanced GCE Physics B (Advancing Physics) 7888
June 2004 Assessment Session

Unit Threshold Marks

Unit		Maximum Mark	a	b	c	d	e	u
2863A	Raw	127	96	86	76	66	56	0
	UMS	100	80	70	60	50	40	0
2863B	Raw	127	96	86	76	66	56	0
	UMS	100	80	70	60	50	40	0
2864A	Raw	119	92	82	72	62	53	0
	UMS	110	88	77	66	55	44	0
2864B	Raw	119	92	82	73	64	55	0
	UMS	110	88	77	66	55	44	0
2865	Raw	90	66	59	52	46	40	0
	UMS	90	72	63	54	45	36	0

Specification Aggregation Results

Overall threshold marks in UMS (i.e. after conversion of raw marks to uniform marks)

	Maximum Mark	A	B	C	D	E	U
7888	600	480	420	360	300	240	0

The cumulative percentage of candidates awarded each grade was as follows:

	A	B	C	D	E	U	Total Number of Candidates
7888	30.7	52.9	73.0	88.2	96.9	100.0	5214

Physics B (Advancing Physics) mark schemes - an introduction

Just as the philosophy of the *Advancing Physics* course develops the student's understanding of Physics, so the philosophy of the examination rewards the candidate for showing that understanding. These mark schemes must be viewed in that light, for in practice the examiners' standardisation meeting is of at least equal importance.

The following points need to be borne in mind when reading the published mark schemes:

- Alternative approaches to a question are rewarded equally with that given in the scheme, provided that the physics is sound. As an example, when a candidate is required to "Show that..." followed by a numerical value, it is always possible to work back from the required value to the data.
- Open questions, such as the questions in section C permit a very wide variety of approaches, and the candidate's own approach must be rewarded according to the degree to which it has been successful. Real examples of differing approaches are discussed in standardisation meetings, and specimen answers produced by candidates are used as 'case law' for examiners when marking scripts.
- Final and intermediate calculated values in the schemes are given to assist the examiners in spotting whether candidates are proceeding correctly. Mark schemes frequently give calculated values to degrees of precision greater than those warranted by the data, to show values that one might expect to see in candidates' working.
- Where a calculation is worth two marks, one mark is generally given for the method, and the other for the evaluation of the quantity to be calculated.
- If part of a question uses a value calculated earlier, any error in the former result is not penalised further, being counted as *error carried forward*: the candidate's own previous result is taken as correct for the subsequent calculation.
- Inappropriate numbers of significant figures in a final answer are penalised by the loss of a mark, generally once per examination paper. The maximum number of significant figures deemed to be permissible is one more than that given in the data; two more significant figures would be excessive. This does not apply in questions where candidates are required to show that a given value is correct.
- Where units are not provided in the question or answer line the candidate is expected to give the units used in the answer.
- Quality of written communication will be assessed where there are opportunities to write extended prose.

SECTION C

The outline mark schemes given here will be given more clarity by the papers seen when the examination is taken. Some of these scripts will be used as case law to establish the quality of answer required to gain the marks available.
It is not possible to write a mark scheme that anticipates every example which students have studied.

For some of the longer descriptive questions three marks will be used (in scheme called the 1/2/3 style).

1 will indicate an attempt has been made
2 will indicate the description is satisfactory, but contains errors
3 will indicate the description is essentially correct

Qn	Expected Answers	Marks	Additional guidance
1	**Section A** tough ✓	1	
2a; b; c	i) **B** ii) **A** ✓ ; a light line / low values AW ✓ ; smoothing / averaging / mean / median AW ✓	1 1 1	both for the mark at 10 / near zero NOT just filter
3a b	r correctly labelled ✓ ; rearrangement or substitution $\sin r = \sin 80°/ 1.3$ ✓ ; correct value for $r = 49.(2)°$ ✓ ; accept 1 / 2 / 3 S.F. ✓	1 1 2	 $\sin 80° / \sin r = 1.3$ S.F. mark not penalty accept 50°
4a b	= 220 / 880 / = ¼ / 1 : 4 ✓; method = 220 x 6 / (220+880) / correct symbolic✓ ; evaluation = 1.2 V ✓	1 1 1	accept 0.25 NOT 4 accept 6 / 5
5a b	$P = IV = IIR = (I^2R)$ / $P/I = I$ R and $P = I^2R$ ✓ ; 4 ✓	1 1	 NO ecf from (a)
6	e.g. rotate **T** / **R** / grille / slit (about x-axis) ✓ ; loudness varies ✓ ; reaches zero / minimum after 90° rotation ora ✓	1 1 1	accept any other valid method e.g.rotating a metal grille 1/2/3 style AW
7ai; ii bi;ii	50 μs ✓ ; 20 000 Hz ✓ ; 3 bits ✓ ; 3×10^6 bits s^{-1} ✓ Total section A	1 1 2 20	accept up to 52μs ecf on 1/T ecf on bits x 10^6

Qn	Expected Answers	Marks	Additional guidance
	Section B		
8a;	Angle of incident ray correct by eye ✓ ;	1	
b;	adv. wider angle of view ✓; disadv. missing angles / non-continuous field of view / hazard ✓;	1 1	NOT see more other sensible suggestions
ci	$I = P / V$ / = 50 / 12 ✓ ; = 4.17 / 4.2 A ✓ ;	2	rearrange ; decimal evaluation i and ii
ii	($G = I / V$) = 4.17 / 12 ✓ ; = 0.347 S ✓ ;	2	allow ecf on 4.0 A i.e. 0.33 S
iii	$t = G L / \sigma h$ OR $A = G L / \sigma$ ✓ ; = 0.347 × 0.2 / (3.1 × 10 ^{5} × 0.08) OR = 2.2 x 10^{-7} m^2✓ ; = 2.8 × 10 $^{-6}$ m ✓	1 1 1	rearrangement substitution / evaluation final evaluation ecf
		10	
9a	50 ± 20 pixels ✓ ;	1	
b	135 / (a) = 2 or 3 or 4 or 5 (to 1 S.F.) ✓ ;	1	must match their (a)
c	same length per pixel AW ✓ ;	1	accept same image
d	1.28 M(bits) ✓ ;	1	accept 1.22 M(bits)
ei	(M = v / u) = 0.16 / 2 x 10^5 ✓ ; (= 8 x 10^{-7}) ora	1	
ii	10 $^{-3}$ / 8 × 10 $^{-7}$ = 1.25 × 10^3 m ✓ ;	1	
iii;	use of geometry similar triangles / equal angles ✓ ;	1	AW
f	$1/u \approx 0$ ✓ ; so $1/v \approx 1/f$ (and $v \approx f$) ✓ OR correct numerical / curvature arguments	2	complete argument for both marks
		9	
10ai	any straight line of best fit judged by eye	1	
ii	**1.** 6.0 ± 0.2 V / consistent with the y-intercept of their graph	1	
	2. r = gradient / $(\mathcal{E} - V) / I$ / = V_{LOST} / I ✓ ; e.g. = (6.0 – 0) / 2.0 ✓ ; = 3.0 Ω ✓ no working max 1	1 2	any correct method ; substitution ; evaluation consistent with their graph values
b	(total) delivered internally and externally / of battery ✓ (dissipated) in internal resistor ✓ ;	1 1	or whole circuit NOT in heat
ci	$R = V / I$ = <u>3</u>(.0)Ω ✓ and $P = I V$ = <u>3</u>(.0) W ✓ ;	2	
ii	(efficiency = $I V / I \mathcal{E}$ = 3.0 / 6.0) = 0.5 / 50% ✓ ;	1	consistent with graph
iii	Power = 2.5 ± 0.1 W / 1.6 ± 0.1 W / 1.9 ± 0.1 W UP ✓	1	consistent calculation of P from a graph point
		11	
11a	$\sigma = \varepsilon E$ = 0.05 x 5.0 x 10 ^{9} any arrangement ✓ ;	1	correct substitution
b	proportional up to point (250 MPa , 5%) ✓ ; any shape ending at point (300MPa , 25%) ✓ ;	1 1	no line no marks
ci;	$A = \pi R^2 = \pi$ x (25 x 10 $^{-6}$) ^{2} = 1.96 x 10 $^{-9}$ m^2 ✓ ;	1	evidence of evaluation
ii	$F = \sigma A$ / = 3.0 x 10 ^{8} x 1.96 x 10 $^{-9}$ ✓ ;= 0.59 / 0.6 N ✓ ;	2	method ; evaluation
di	any mechanical property ✓ of a composite related to microstructure ✓ ; explain by ref to matrix <u>and</u> fibres ; e.g. strength / stiffness : of fibres shifted to matrix / toughness : stress shared by matrix to other fibres / anisotropy : stronger axially than transverse - split ends	2	AW reward other sensible physics suggestions NOT ductile
ii	suggest: coiled protein molecules can uncoil and coil up again when stress is removed ✓ ; weak bonds between coiled molecules can be broken under stress then reform when stress is removed / strong sulphur bonds to matrix pull coils back to shape ✓	1 1	reward sensible suggestions or AW but NOT spring analogy
		10	
		40	

Qn	Expected Answers	Marks	Additional guidance
	Total section B		
Qn	**Expected Answers**	**Marks**	**Additional guidance**
	Section C		
12ai	e.g. text / logos ✓; by FAX✓;	2	
ii	a frequency estimate ✓ 64 kHz (allow kbits per s) ✓; frequency at which binary bits of information are transmitted down the telephone line from transmitting to receiving FAX machines ✓	2 1	sensible for example chosen with unit accept speech / carrier / sampling frequencies
iii	higher f enables greater rate of information transfer ✓	1	NOT more data
b	1/2/3 style ✓ ✓ ✓ analogue – continuously variable signal digital – two level / binary signal accept correct diagrams or explanation to max 3	3	 AW
c	adv - communication on the move / worldwide ✓; exp – emergency services can be contacted immediately at an accident ✓; disadv – mobile phones ringing in trains / concerts ✓; exp – annoyance to other passengers / audience ✓;	1 1 1 1	allow any sensible justified cases of making physics connect
	Total	13	
13a	e.g. light intensity ✓; LDR ✓	2	allow amount of fuel
b	circuit diagram 1/2/3 style ✓ ✓ ✓ penalise incorrect circuit symbols	3	full marks for active sensor circuit with suitable output monitor
ci	e.g. vary light intensity and measure (against a known standard / digital luxmeter); plot graph of output p.d. against intensity; gradient of graph / AW for sensitivity OR 1/2/3 style ✓ ✓ ✓	 3	vary input and measure correct plot measure sensitivity
ii	e.g. 3 ✓ mV per lux / mV per W m^{-2} ;✓	2	unit must relate to b / c value plus incorrect unit scores 0
iii	any change to fixed resistor in potential divider / increase emf / amplify (output); to give appropriate output alteration; to increase range of output (for similar input change) OR 1/2/3 style ✓ ✓ ✓	1 1 1	easy first mark look back to circuit tough third mark other approaches
	Total	13	
	Quality of written communication	4	
	Total section C	30	

QoWC **Marking quality of written communication**

The appropriate mark (0-4) should be awarded based on the candidate's quality of written communication in Section C of the paper.

4 max The candidate will express complex ideas extremely clearly and fluently. Answers are structured logically and concisely, so that the candidate communicates effectively. Information is presented in the most appropriate form (which may include graphs, diagrams or charts where their use would enhance communication). The candidate spells, punctuates and uses the rules of grammar with almost faultless accuracy, deploying a wide range of grammatical constructions and specialist terms.

3 The candidate will express moderately complex ideas clearly and reasonably fluently. Answers are structured logically and concisely, so that the candidate generally communicates effectively. Information is not always presented in the most appropriate form. The candidate spells, punctuates and uses the rules of grammar with reasonable accuracy; a range of specialist terms are used appropriately.

2 The candidate will express moderately complex ideas fairly clearly but not always fluently. Answers may not be structured clearly. The candidate spells, punctuates and uses the rules of grammar with some errors; a limited range of specialist terms are used appropriately.

1 The candidate will express simple ideas clearly, but may be imprecise and awkward in dealing with complex or subtle concepts. Arguments may be of doubtful relevance or obscurely presented. Errors in grammar, punctuation and spelling may be noticeable and intrusive, suggesting weakness in these areas.

0 The candidate is unable to express simple ideas clearly; there are severe shortcomings in the organisation and presentation of the answer, leading to a failure to communicate knowledge and ideas. There are significant errors in the use of language which makes the candidate's meaning uncertain.

Qn	Expected Answers	Marks	Additional guidance
	Section A		
1 (a)	5×10^{-4} (m) ✓	1	
1 (b)	500 (nm) ✓	1	or 5×10^{2} (nm)
2	$(3.0)^2/(1.5)^2$ or 9/2.25 or 2^2 ✓ ratio = 4 ✓	2	for ratio = 4 ✓✓
3 (a)	$t = 2s/(u + v)$ ✓ $t = (v - u)/a$ ✓	2	
3(b)	$(2s/(u + v) = (v - u)/a)$ to $2as = (uv - u^2 + v^2 - uv)$ ✓ or $2as = v^2 - u^2$	1	not $2as = u^2 - v^2$
4	2 correct additional points (other than 0,0) ✓✓ <u>appropriate</u> line through the points plotted and (0,0)✓	3	error in point plotted –1 judge line through points <u>plotted</u>
5(a)	1.0×10^{15} (Hz) ✓ (1.0 Hz = zero)	1	
5(b)	below f_o no electrons (above f_o you get electrons)✓ min f corresponds to min photon energy = hf ✓	2	
5(c)	$(10 \times 10^{-19})/(1.5 \times 10^{15}) = 6.7 \times 10^{-34}$ ✓ (J s) penalise more than 3 sf	1	accept 1 s.f.
6	Line/curve up from (0,0) to t_1 ✓ plateau from t_1 to t_2 ✓ Line/curve down from plateau to $(t_3,0)$ ✓	3	
7(a)	90° or 270° or $\pi/2$ or $3\pi/2$ or ¼ of a cycle✓ (not $\lambda/4$)	1	
7(b)	A at 6 o'clock ✓ B at 9 o'clock ✓	2	
	Section A total	20	

Qn	Expected Answers	Marks	Additional guidance
	Section B		
8 (a)(i)	correct standing wave ✓ one A and one N labelled ✓	2	
(ii)	**clear** method ✓ showing $l_2 - l_1 = \lambda/2$	1	
(iii) 1	$0.506 - 0.170 = \lambda/2$ ✓ $\lambda = 0.672$ (m) ✓ (0.67)	2	not by $v = f\lambda$ here, must be using $l_2 - l_1 = \lambda/2$
(iii) 2	$v = 500 \times 0.672$ ✓ = 336 m s^{-1} ✓ (ecf from (a)(iii)) accept 340 m s^{-1}	2	0.67 gives 335
(b)	smaller wavelength ✓ smaller distances (to measure) ✓ less accuracy **in the measurements** ✓	3	
	total	10	
9 (a)(i)	orange; brighter; broader(wider) ✓ ✓	2	maximum 2 marks
(ii)	2 wavelengths (or frequencies) ✓	1	
(iii)	Shorter λ ✓ $\sin\theta = \lambda/d$ idea ✓	2	or rotating phasors argument
(iv)	both wavelengths contribute in phase (AW) ✓	1	or rotating phasors argument
(b) (i)	larger distance from orange ✓ approx double ✓	2	see acceptable limits
(ii)	'd' (slit separation) is halved (or less) ✓ $\sin \theta = \lambda/d$ idea ✓ (or bigger angle to give same path diff)	2	rotating phasors idea
	total	10	

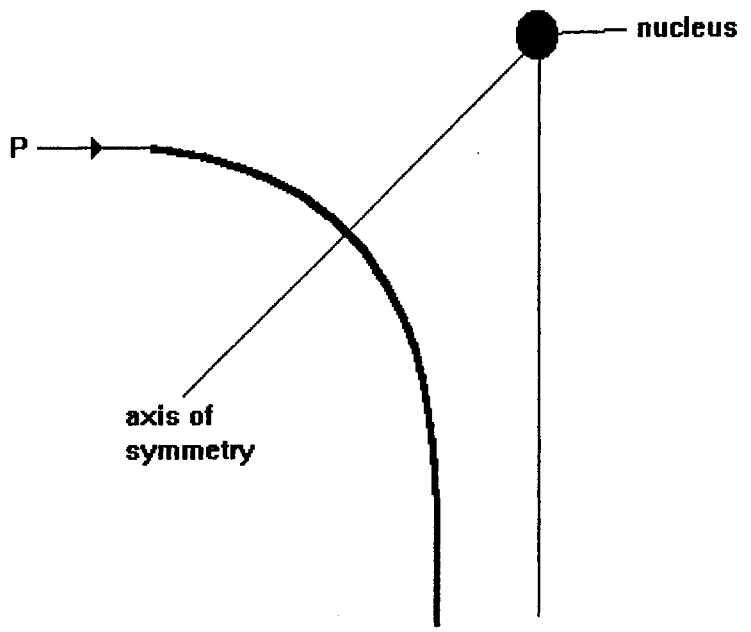
Qn	Expected Answers	Marks	Additional guidance
10 (a)(i)	17 cos 30 or 17 sin 60✓ (= 14.7 m s^{-1})	1	
(ii)	accelerating / because of gravity or gravity reduces vertical component✓	1	
(iii)	s = (14.7x1.5) - $^1/_2$x9.8x$(1.5)^2$ $✓_m✓_s$ = 11 m ✓ (approx) (g = 10 gives 10.83)	3	or by $v^2 = u^2 - 2as$ or s = (u + v)t/2
(b)(i)	time less ✓ smaller vertical height (or smaller v_Y)✓ (or horizontal velocity greater, distance same (t = s/v))	2	
(ii)	Horiz component of velocity greater✓ but time less and s = vt ✓	2	
(iii)	first ball since it will bounce more ✓, less friction ✓ (or second ball because horizontal component of velocity is greater ✓ so friction takes 'longer' to stop it ✓)	2	2 marks for (i) a plausible statement, (ii) supported by the physics
	total	11	
11 (a)(i)	1 - 2.0 (km h^{-1}) ✓ 2 +8.0(km h^{-1}) ✓	2	For omitting/confusing + and – signs (max 1)
(ii)	Using t = x/v ✓ 2/2 + 2/8 ✓ (= 1.25 hr) no ecf here	2	
(b)(i)	correct drawing/sketch of velocity vectors ✓ accuracy of scale giving 37° or sin θ = 0.6 = 37° ✓	2	
(ii)	Using accurate scale drawing in (b)(i) ✓ = 4.0 km h^{-1} ✓ (or by trig / pythgoras ✓ answer shown ✓)	2	
(c)	for showing position of P is l km from A and B ✓ for scale drawing or tan θ = 0.5 ✓ (.. θ = 26.6)	2	
	total	10	
	Section B total	41	

Qn	Expected Answers	Marks	Additional guidance
	Section C		
12 (a)	for stating a **quantum** phenomenon	1	see supplementary sheets
(b)	essentially correct ✓✓✓ satisfactory but with some significant error/omission ✓✓ some attempt made ✓	3	
(c)	for observations that **could** be made with the apparatus described up to 4 ✓$_o$✓$_o$ ✓$_o$ ✓$_o$	4	mark ✓$_o$ and ✓$_e$ in both (c) and (d)
(d)	for points of explanation ✓$_e$✓$_e$✓$_e$✓$_e$ (not all points of explanation will necessarily be quantum)	4	must be rooted in a quantum explanation
	total	12	
13 (a)(i)	for stating type of wave ✓	1	see supplementary sheets
(a) (ii)	sensible order of magnitude of wavelength ✓ sensible order of magnitude of velocity ✓	2	
(b)	essentially correct ✓✓✓ satisfactory with some significant error/omission ✓✓ some attempt made ✓	3	
(c)	1 enough detail to perform operation ✓	1	
(d)	for three salient observations that could be made ✓✓✓	3	
	for explaining each of the observations described ✓✓✓	3	Bright ..
	total	13	
	Quality of Written Communication	4	
	Section C total	29	
	Total for paper	90	

Question	Expected Answers	Marks
1 (a)	10^{-21} J ✓	1
(b)	10^{-15} J ✓	1
2 (a)	factor =440/122✓ = 3.6✓ (two marks for answer)	2
(b)	light from more distant objects has travelled for a greater time/distance✓ so more expansion. ✓ AW (penalise lack of clarity)	2
3 (a)	valid test on two or more pairs of data ✓ (showing constant ratio) valid conclusion ✓ OR: linear graph and clear argument/log graph ✓ quality✓	2
	e.g. radioactive decay, decay of charge on capacitor ✓	
(b)		1
	$pV = nRT$ ✓ $V = nRT/p = 2 \times 8.3 \times 310/1.5 \times 10^5 = 3.4 \times 10^{-2}$ m^3 ✓	
4		2
	$k = F/x = 9.81 \times 0.4/22 \times 10^{-3}$✓ = 178 N m^{-1} ✓ ORA penalise lack of quality	
5 (a)	$f = (1/2\pi).(k/m)^{½}$ ✓ = $0.16 \times (180/0.4)^{½}$ ✓ = 3.4 Hz✓ ecf	2
	(If time period used without frequency calculation one mark only)	
(b)		3
	$2.7 \times 7.3 = 19.7$ kg m s^{-1} ✓	
6	force (on clown) = rate of change of momentum ✓, and clear Newton 3 argument	
(a)	relating to clown and water. ✓	1
(b)	(as water bounces off clown) the velocity change is greater than 7.3 ms^{-1} ✓ so change of momentum per second is greater than 19.7 N so force on clown increased. ✓	2
(c)	**Section A total 21**	2
7 (a) (i)	$E = ½CV^2 = ½ \times 200 \times 10^{-6} \times 390^2$ ✓= 15 (.2) J ✓	2
(ii)	P = 15(.2)/0.01✓ = 1500 W✓ ecf	2
(iii)	Pd or current not constant over time ✓ so the power (energy per second) is falling ✓.	2
	$5RC = 0.01$ $R = 0.01/(5 \times 200 \times 10^{-6})$ ✓ = 10 Ω.	
(b)		2
	$E \alpha V^2$ $V \alpha E^{1/2}$ ✓ therefore factor increase is √2 ✓ or by calculation of new value	
(c)	✓ leading to factor ✓ ecf a (I)	2
	Lower pd across single capacitor ✓ so less chance of breakdown. ✓ or sensible alternatives leading to logical conclusion. (e.g.; smaller size leading to	2
(d)	easier implantation)	

8(a) (i)	Greatest displacement ✓ from equilibrium position ✓ (can use diagram).	2
(ii)	0 mm ✓	1
(iii)	0 m s^{-2} ✓	1
(iv)	$a = (-)\ 4\pi^2 f^2 x = (-)\ 4\pi^2 \times 100 \times 0.035$✓ = 138 m s^{-2}✓ SF penalty ($\leq$ 3 sf OK)	2
(v)	either calculate force due to oscillation ✓ and compare with weight ✓ or compare values of accelerations ✓ and link to accelerating force ✓ ecf.	2
(b) (i)	Natural frequency of aerial ✓ same as driving/satellite frequency ✓ AW	2
(ii)	Sensible change ✓ to damp or shift resonant frequency ✓.	2
9(a)	Calculating energy as 108 kJ (can be implicit) ✓ Temp change = 108000/(0.4 x 4200) ✓ = 65° C ✓.	3
(b)	As T increases ($e^{-E/kT}$ gets bigger) BF bigger ✓ hence greater chance/proportion of molecules entering vapour state ✓. AW	2
(c) (i)	1st marking point: As the number of molecules in the vapour increases so does the number of collisions (per second) OR Pressure = Force / Area argument ✓ 2nd marking point: consideration of rate of change of momentum on collision (with the lid) ✓. OR explanation based on gas equations ✓ stating constant volume ✓	2
(c)(ii)	Faster collisions with lid (giving greater change of momentum per collision) ✓ more collisions per unit time ✓ OR explanation based on gas equations ✓ stating constant volume ✓	2
(c) (iii)	Sensible comment relating to lid blowing off/soup all over the microwave ✓.	1

10 (a)	Straight line ✓ through origin ✓	2
(b)(i)	$F = m\,a = m \times v^2/R$ ✓	1
(ii)	$F = (-)G\,Mm/R^2$ ✓	1
(iii)	$mv^2/R = G\,Mm/R^2$ ✓	1
(iv)	$(2\pi R/T)^2 R = GM$ ✓ worked through to given equation ✓ (or alternative route) ✓✓	2
(v)	$M_s = 4\,\pi^2(1.5 \times 10^{11})^3/\ 6.7 \times 10^{-11} \times (3.2 \times 10^7)^2$ ✓ $= 1.94 \times 10^{30}$ ✓	2
(c)	suggestion linked to ✓ sensible explanation ✓.	2
	QoWC Section B total	4 49

Question	Expected Answer	Mark
1 (a)	50	1
1 (b)	Calculate: $\frac{V_1}{V_2} = \frac{n_1}{n_2}$ (eor) n_2 = 1840 × (6/230) = 48 (award [2] for correct answer)	1 1
2	rearranged formula ($k = Vr/Q$) , Q is C, r is m V has units of J C^{-1} (wtte) (so units of k are J C^{-1} m C^{-1}) accept reverse argument	1 1
3 (a)	smooth curve downwards (by myopic eye) emerges between 0 and 2.5 cm left of vertical line through nucleus  	1 1
3 (b)	B	1

Question	Expected Answer	Mark
4 (a) 4 (b)	($30\times10^{-3} \times 40 \times 80 = 96$) C risk = $3 \times 30\times10^{-3} \times 40 = 3.6$ % (accept 0.036 with % crossed out).	1 1
5 (a) 5 (b)	10^{-14} m 10^{-18} C	1 1
6 (a) 6 (b)	horizontal line touching X (by eye) arrow from right to left $\leftarrow$ pointing towards charged conductor spacing between equipotentials/circles/lines increases (with increasing distance) (ora) answer in terms field lines worth [0]	1 1 1
7 (a) 7 (b)	neutrons (accept circled in list) C (accept positron or ring around positron)	1 1
8 (a) 8 (b)	Calculate: $E = kQ/r^2$ (eor) $Q = Er^2/k = 5\times10^6 \times 0.025^2 / 9\times10^9 = 3.5\times10^{-7}$ C correct answer worth [2] (accept 3×10^{-7}) any of the following • air becomes a conductor / breaks down • charge/current leaks from surface of conductor • air molecules/atoms are ionised by the electric field • sparks carry charge away from conductor • field affects conductance/resistance of air • stray ions neutralise charge	1 1 1

Question	Expected Answer	Mark
9(a)(i)	continuous loop passing through the letters N and S (by eye) threading the coil, mostly within the iron core	1 1
9(a)(ii)	any of the following, maximum [2] (wtte) • guides/conducts flux lines (through coil) / links flux to coil • becomes magnetised by <u>rotor</u> • easy to magnetise / demagnetise / realign magnetic dipoles (wtte) • increases the strength of the field / more flux (in the coil) • <u>high</u> permeance / permeability • <u>low</u> remanence / hysteresis / energy loss (wtte) • provides magnetic circuit (for flux) Iron is a magnetic material worth [0]	2
9(b)(i)	sinusoidal shape, correct period, constant amplitude, at least one cycle (by eye) correct phase, either $\pi/2$ ahead or behind	1 1
9(b)(ii)	Show: (revolutions per second) = $1/15\times10^{-3}$ = <u>67</u> NOT 66 or 70 (accept reverse argument (14 ms) for full marks)	1 1
9(c)	any of the following, maximum [3] • reduces eddy currents (accepts stops) • caused by changes of flux (linkage) (in the core) • by increasing resistance / decreasing conductance of the core • eddy currents create magnetic field / flux • which (partially) cancel out field / flux of rotor (i.e. Lenz's Law) • eddy currents reduce the field / flux (in the coil/core) • eddy currents dissipate (heat) energy in the core • (laminations) increase flux / flux density / flux linkage (in coil/core) back emf is neutral	3

Question	Expected Answer	Mark
10(a)(i)	Calculate: proton number = 94 neutron number = 239 - 94 = 145 ecf incorrect proton or neutron number: total mass = $94 \times 1.673\times10^{-27} + 145 \times 1.674\times10^{-27} = 3.999\times10^{-25}$ kg accept $4(.000)\times10^{-25}$ kg and no incorrect calculation for [3] accept 5.573×10^{-25} for [2] i.e. 239 neutrons and 94 protons accept 3.994×10^{-25} for [1] i.e. 94 neutrons and 145 protons 4.001×10^{-25} worth [0] i.e. 239 neutrons 3.998×10^{-25} worth [0] i.e. 239 protons	1 1 1
10(a)(ii)	any of the following, maximum [2] • difference caused by <u>binding energy</u> • (strong) forces/bonds hold neutrons and protons in nucleus • particles have less energy/mass in the nucleus (ora) • $E = mc^2$ (wtte) • do work to separate the particles in a nucleus	2
10(b)(i)	$\lambda/2 = 2 \times 7.4\times10^{-15}$ $\lambda = 4 \times 7.4\times10^{-15} = \underline{2.96}\times10^{-14}$ m ($= 3\times10^{-14}$ m)	 1
10(b)(ii)	Show: $\lambda = h/p$ $p = h/\lambda$ (eor for rearranged formula) $p = 6.6\times10^{-34} / 2.96\times10^{-14} = 2.23\times10^{-20}$ N s (or kg m s^{-1}) ecf incorrect λ: 2.20×10^{-20} N s for 3×10^{-14} m accept reverse calculation for [2]	0 1 1
10(b)(iii)	Calculate: EITHER $E_k = p^2/2m$ OR $E_k = mv^2/2$, $p = mv$ $E_k = (2.2\times10^{-20})^2/2 \times 6.7\times10^{-27} = 3.6\times10^{-14}$ J ACCEPT 3.7×10^{-14} NOT 4×10^{-14} ACCEPT $3(.0)\times10^{-14}$ J for 2×10^{-20} N s,	1 1

Question	Expected Answer	Mark
10(c)	plausible suggestion of mechanism argument linking mechanism to decay e.g. some energy (levels) above the ground state give the particle enough energy to escape collisions (with other particles) in nucleus gives alpha particle enough energy to escape when alpha particle is raised above ground state it may be able to tunnel through the walls of the well particle has finite chance of being outside nucleus because standing wave extends beyond the potential well	1 1

Question	Expected Answer	Mark
11(a)(i)	mass numbers correct charge numbers correct $^{239}_{94}Pu \rightarrow ^{235}_{92}U + ^{4}_{2}He$	1 1
11(a)(ii)	Show: $\lambda = 0.693/T_{1/2}$ $\lambda = 0.693/7.6\times10^{11} = 9.12\times10^{-13}\ s^{-1}$ ecf incorrect decay constant: $A = \lambda N$ $A = 9.12\times10^{-13} \times 2.5\times10^{14} = \underline{228}$ Bq (accept 230) (which is >> 1 Bq) accept reverse argument showing 1.1×10^{12} nuclei for 1 Bq for [2]	0 1 0 1
11(a)(iii)	$m = 239 \times 1.7\times10^{-27} \times 2.5\times10^{14} = 1(.0)\times10^{-10}$ kg	1
11(a)(iv)	any of the following, maximum [3] • no risk from alpha particles from outside the body (wtte) • alpha particles have short range / low penetration • produce very heavy ionisation / high quality factor • because of their high charge / mass • can damage cells so that they <u>mutate</u> (wtte) NOT kill cells • only a few cells/local tissue is irradiated (wtte) • leading to a high dose for that tissue reference to beta particles / gamma photons are neutral	3
11(b)(i)	8	1
11(b)(ii)	Calculate: $E_e = kQq/r$ $E_e = 9\times10^{9} \times 1.5\times10^{-17} \times 1.6\times10^{-19} / 7.4\times10^{-14} = 2.9\times10^{-13}$ J	1 1

Question	Expected Answer	Mark
12(a)	Calculate: $F = Bqv$ $v = F/Bq = 9.6\times10^{-23} / 0.12 \times 1.6\times10^{-19}$ $= 5.0\times10^{-3}$ $\mathrm{m\ s^{-1}}$ ACCEPT 5 mm $\mathrm{s^{-1}}$, 0.5 cm $\mathrm{s^{-1}}$	0 1 1 1
12(b)	any of the following, maximum [2] • magnetic force at right angles to field direction • magnetic force at right angles to motion • electrons (NOT charge) pushed to bottom edge of strip • leaving positive ions at the top edge of the strip (ACCEPT holes pushed to the top)	2
12(c)(i)	vertical, evenly spaced lines in field region, at least three downward arrow ↓ on each line	1 1
12(c)(ii)	Show: EITHER $F = eV/d$ OR $E = V/d$, $F = eE$ $F = 1.6\times10^{-19} \times 9.6\times10^{-6} / 16\times10^{-3} = (9.6\times10^{-23}\ \mathrm{N})$	1 1
12(d)	Show: $F_m = Bev$, $F_e = eE$ so $Bev = eE$ $Bev = eV/d$ $V = Bvd$ (= constant × B) watch for confused v and V	1 1 1
	Quality of Written Communication	4

Qn	Expected Answers	Marks	Additional guidance
1 (a)	(i) 5.4 MeV = 5.4×10^6 eV ✓ $= 5.4\times 10^6 \times 1.6\times10^{-19}$J = 8.6×10^{-13} J ✓ (ii) $\frac{1}{2}mv^2 = 8.6\times 10^{-13}$ J $\Rightarrow v = \sqrt{\dfrac{2\times 8.6\times10^{-13}}{6.6\times10^{-27}}}$ ✓m $= 1.6 \times 10^7$ m s^{-1} ✓e	2 2	Can use 9×10^{-13} J ora from v=2×10^7 m s^{-1}
(b)	(i) 206✓ (ii) $0=206v + 4\times 2 \times 10^7$ m s^{-1}✓ $\Rightarrow v = (-)\ 3.9\times 10^5$ m s^{-1}✓ (iii) v smaller, m bigger ✓ (this factor occurs) twice in v^2 and once in m so $\frac{1}{2}mv^2$ smaller ✓	1 2 2	First mark is application of conservation of momentum Using 1.6×10^7 m s^{-1} $\Rightarrow$ $v = 3.1\times 10^5$ m s^{-1} Can use masses in kg Can refer to same p to justify m/v relationship Arithmetic method OK
2 (a)	Reference to proton-electron (beta) charge balance✓	1	83 = 84 -1+0 is ✓
(b)	Not ionising (and detectors observe ionisation)✓	1	
(c)	(i) Δm =209.93845 –209.93666 – 0.00055= 0.00124u ✓ $= 0.00124 \times 1.7\times10^{-27}$ kg = 2.11×10^{-30} kg ✓ (2.something small $\times10^{-30}$ kg allows for rounding error) (ii) $E = mc^2 = 2.11\times10^{-30}\times(3.0\times10^8)^2 = 1.9\times10^{-13}$ J✓m✓e	2 2	Ecf possible here
3 (a)	annihilation produces 2 photons in opposite directions ✓	1	Could refer to coincidence counting
(b)	Neutron slower than positron / neutron less easily absorbed than positron/ Cd nuclei rarer than electrons ✓	1	Any reasonable suggestion
(c)	(i) (Counts of) photon pair (+ single photon just after) ✓ (ii) Background radiation/cosmic rays/stray photons\ ✓	1 1	Allow neutrinos
(d)	Reduces noise/background radiation ✓ By absorb all cosmic radiation/AW ✓	2	Must specify/imply radiation from space not rocks for second ✓.

Qn	Expected Answers	Marks	Additional guidance
4 (a)	(i) number (of neutrinos) per (unit) time✓ per (unit) area✓ (ii) flux = $2 \times 10^{38} / 2.8 \times 10^{23}$ m^2 = 7.1×10^{14} m^{-2} s^{-1}✓m✓e	2 2	or per m^2
(b)	(i) Area between 0.2 and 1.2 m^2✓ (ii) Number = area×7.1×10^{14} m^{-2} s^{-1} ≈ 4×10^{14} s^{-1}✓m✓e (iii) Number absorbed s^{-1} = $4\times10^{14}/10^{18}$ ✓ = 4×10^{-4} so energy absorbed/year = $4\times10^{-4}\times3.2\times10^{7}\times1.6\times10^{-13}$J = 2.1×10^{-9} J ✓ absorbed dose= 2.1×10^{-9} J /65 kg = 3×10^{-11} ✓ Gy/grays/J kg^{-1}✓ (iv) Insignificant dose/ low quality factor/not much energy absorbed/ weakly interacting✓	1 2 4 1	sfe for > 2 sf can use7×10^{14} m^{-2} s^{-1} ecf for neutrino numbers and area
5 (a)	(i) steadily increasing line of (roughly) constant gradient✓ (ii) increases from 0 and (quickly) levels off✓	1 1	Allow large random variations (see (d))
(b)	$T_{½}$ = ln 2/2.3×10^{-7} s^{-1} =3.0×10^{6} s (= 34.9 days) ≈ 2.6×10^{6} s ✓m✓e	2	A stated or implied comparison with a month is needed.
(c)	Low count rate hard to distinguish from background / tiny amount of Ar compared with the vast volume of C_2Cl_4 ✓	1	
(d)	neutrino interactions are infrequent and random✓; Ar-37 decays also infrequent and random ✓ ; small counts tend to fluctuate ✓	2	Any two relevant points; may refer to elliptical orbit of Earth or to neutrino oscillations
6(a)	Distance = $3.0\times10^{8}\times3.2\times10^{7}\times40\,000$ m = 3.8×10^{20} m ✓m✓e	2	
(b)	Continual absorption and emission✓ random changes in direction ✓	2	Can compare with gas diffusion for one ✓
(c)	T 1000 (actually 1034) × higher ✓ ⇒ E 1000× higher ✓ ⇒ f 1000× higher ✓	3	Arithmetically: $E=kT$ calc ✓, $E=hf$ calc ✓ and ratio ✓
(d)	$\sqrt{N}L = 2.0\times10^{8}$ m ⇒ $NL^2 = 4.0\times10^{16}$ m^2 $NL = 4.0\times10^{20}$ m ⇒ $NL^2/NL = L = 4.0\times10^{16}$ m^2/4.0×10^{20} m = 1.0×10^{-4}m ✓m✓m✓e	3	✓m for combining two equations ✓m for rearranging. L « solar radius for ✓e

7 (a)	iron nucleus has most negative binding energy/ greatest mass defect/is most stable ✓ so no stability gained by further fusion ✓	2	
(b)	(i) time delay of 340 000 years (impossibly huge) ✓ (ii) Hubble's Law / cosmological redshift concerns separate groups of galaxies ✓ this galaxy (Larger Magellanic Cloud) is gravitationally bound to ours/AW ✓	1 2	(ii) Allow: supernova's galaxy relatively close✓ so small redshift✓
(c)	As star explodes, matter ejected (at exceedingly high speed) so less obstruction for photons✓	1	
8 (a)	(i) $IVt = 10\times230\times3\times60$ J = 4.1×10^{5} J $\approx 4\times10^{5}$ J ✓m✓e (ii) $mc\Delta T = 1\times4200\times(100-20) = 3.3\times10^{5}$ J $\approx 3\times10^{5}$ J ✓m✓e	2 2	
(b)	<u>Photons</u> have higher average energy ✓ ; therefore they are higher frequency ✓	2	Quoting $E=hf=kT$ implies photons.
(c)	(i) $E=hf = 6.6\times10^{-34}$ J s × 4.0×10^{14} Hz = 2.6×10^{-19} J $\approx 3\times10^{-19}$ J ✓m✓e (ii) Number s^{-1} = 1000W/ 3×10^{-19} J = 3×10^{21} s^{-1} ✓m✓e	2 2	Can use 2.6×10^{-19} J in (ii) to get 4×10^{21} s^{-1} Must have 1000 J in 1 s
(d)	Transparent case ✓ so many photons escape ✓ / less well absorbed ✓/ bubbles reflect photons✓ so not penetrating all of water ✓	2	✓ for any reasonable suggestion including lower power rating, ✓ for explanation ✓ / ✓✓ for two separate suggested reasons.
(e)	(i) property ✓ explanation ✓ (ii) property ✓ explanation ✓ e.g. insulating✓so little heat lost by conduction✓ /low mass✓ so little energy needed to heat up✓ /low thermal conductivity ✓so cooler outer surface is less dangerous to touch✓ /unreactive material of case✓ so does not rust✓	2 2	Not 'cheap'. Explanation mark must be linked to the property.

9 (a)	(i) $F=GMm/r^2$ ✓ $\Rightarrow g = GM/r^2$ $= 6.7 \times 10^{-11} \times 7.3\times10^{22}/(1700 \times10^3)^2$ $= 1.69$ N kg^{-1} ≈ 1.7 N kg^{-1}✓s✓e (ii) $\Delta V_g=gh = 1.7 \times 10\,000 = 1.7 \times 10^4$ J kg^{-1}✓m✓e unit of J kg^{-1} ✓ (iii) Because g gets weaker as h increases ✓	3 3 1	$g = GM/r$ gets 0 Must use $\Delta V_{grav}= gh$
(b)	(i) Arrow radially inwards ✓ (ii) Presence of atmosphere ✓; excessive frictional forces would stop satellite orbiting/make it spiral in ✓	1 2	Not crashing into mountains or aircraft
(c)	(i) $f = 5$ cm so $P = 1/5\times10^{-2}$ m = 20 D✓ (ii) resolution = 8000 m/1024✓ = 7.8 m ✓ (iii) moving too fast to take clear photos/variation of object distance too significant ✓	1 2 1	(ii) Area resolution (of 61m^2) gets one mark even if unit changed to m^2 pixel^{-1}. Penalise >3 sf (iii) Any reasonable suggestion

Quality of Written Communication Apply in Q3 or Q7 where possible. If these have been omitted or are untypical of the paper, look elsewhere.	4	See QWC criteria (next page)

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