A-Level
Physics

PHYA4 – Fields and Further Mechanics
Mark scheme

2450
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Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

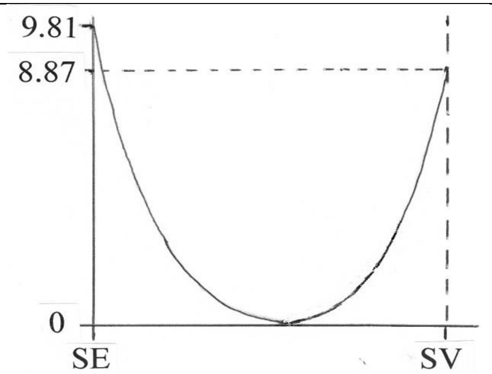
Further copies of this mark scheme are available from aqa.org.uk

Section A

1	**D**	14	**A**
2	**B**	15	**C**
3	**B**	16	**A**
4	**D**	17	**B**
5	**D**	18	**A**
6	**C**	19	**C**
7	**D**	20	**A**
8	**B**	21	**A**
9	**B**	22	**D**
10	**C**	23	**C**
11	**B**	24	**B**
12	**C**	25	**D**
13	**C**		

Question	Answers	Additional Comments/Guidance	Mark	ID details
1(a)(i)	capacitance $\left(=\frac{Q}{V}\right) = \frac{98.2-73.9}{12.0-9.0}$ ✓ = 8.1 (μF) ✓ (± 0.2 μF)	1 mark only if correct value of C is found from a single point. 2 marks if correct value of C is found from at least 2 points and a mean value, or from gradient. (Check graph.) Accept 8 (μF) if from correct working.	2	
1(a)(ii)	additional energy = area between line and Q or V axis ✓ = {½ × (98.2 – 73.9) × 3.0} + {(98.2 – 73.9) × 9.0} ✓ = (36.5 + 218.7) = 255 μJ or 2.6 × 10^{-4} (J) ✓ [**or**, using ½ QV: additional energy = ½ Q_2V_2 – ½ Q_1V_1 ✓ = ½ {(98.2 × 12) – (73.9 × 9)} ✓ = 257 μJ or 2.6 × 10^{-4} (J) ✓] [**or**, using ½ CV^2: additional energy = ½ CV_2^2 – ½ CV_1^2 ✓ = ½ × 8.1 × (12^2 – 9^2) ✓ = 255 μJ or 2.6 × 10^{-4} (J) ✓] [**or**, using ½ Q^2/C: additional energy = ½ Q_2^2/C – ½ Q_1^2/C ✓ = (98.2^2 – 73.9^2) ÷ (2 × 8.1) ✓ = 258 μJ or 2.6 × 10^{-4} (J) ✓]	*First scheme*: alternative for 2nd mark = {½ × (98.2 – 73.9) × 3.0} + {73.9 × 3.0} ✓ *All schemes*: second mark subsumes the first mark. In all methods, allow tolerance of ± 10 μJ in final answer to allow for variation in graph measurements. Allow ECF for incorrect C value from (a)(i).	3	
1(b)(i)	($V = V_0 e^{-t/RC}$ gives) $0.2V_0 = V_0 e^{-t/RC}$ and $0.2 = e^{-45/RC}$ ✓	Condone use of 0.8 for 0.2 in first mark only.	3	

	$\ln 0.2 = -\frac{45}{RC}$ **or** $\ln 5 = \frac{45}{RC}$ ✓ time constant RC = $-\frac{45}{\ln 0.2}$ **or** $\frac{45}{\ln 5}$ = 28(.0) (s) ✓			
1(b)(ii)	resistance of R = $\left(= \frac{\text{time constant}}{C}\right)$ = $\frac{28.0}{470\times10^{-6}}$ ✓ = 5.96 × 10^4 (Ω) or 60 kΩ ✓	Allow ECF for incorrect RC value from (b)(i).	2	
1(b)(iii)	tick in 4th box **only**		1	
Total			11	

Question	Answers	Additional Comments/Guidance	Mark	ID details
2(a)(i)	$M = \frac{4}{3}\pi R^3 \rho$ ✓ combined with $g_S = \frac{GM}{R^2}$ (gives $g_S = \frac{4}{3}\pi G R \rho$) ✓	Do not allow *r* instead of *R* in final answer but condone in early stages of working. Evidence of combination, eg cancelling R^2 required for second mark.	2	
2(a)(ii)	$R = \left(\frac{3g_S}{4\pi G\rho}\right) = \frac{3 \times 8.87}{4\pi \times 6.67 \times 10^{-11} \times 5.24 \times 10^3}$ ✓ gives R = 6.06 × 10^6 (m) ✓ answer to **3SF** ✓	SF mark is independent but may only be awarded after some working is presented.	3	
2(b)	line starts at 9.81 and ends at 8.87 ✓ correct shape curve which falls and rises ✓ falls to zero value near centre of and to right of centre of distance scale ✓ [*Minimum of graph in 3rd point to be >0.5 and <0.75 of SE-SV distance*]	 For 3rd mark accept flatter curve than the above in central region.	3	
Total			8	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3(a)	no external forces (act on the system of particles) [**or** forces between particles are internal forces] ✓	Allow "in a closed system".	1	
3(b)(i)	$N\,V = (-)\,m\,v$ [**or** $N\,V + m\,v = 0$] ✓ (gives) $V = (-)\dfrac{mv}{N}$ ✓	For 2nd mark, V must be the subject of the eqn.	2	
3(b)(ii)	$\frac{1}{2} NV^2 + \frac{1}{2} mv^2 = E$ ✓ substitution for V gives $\dfrac{1}{2}N\left(\dfrac{mv}{N}\right)^2 + E_\alpha = E$ ✓ from which $\dfrac{1}{2}\left(\dfrac{m}{N}\right)mv^2 + E_\alpha = E$ and $\left(\dfrac{m}{N}+1\right)E_\alpha = E$ ✓ rearrangement gives $E_\alpha = \dfrac{E}{\left(\dfrac{m+N}{N}\right)} = \left(\dfrac{N}{N+m}\right)E$ ✓	The 4 marks are for • conservation of energy • substitution for V • separation of E and E_α, with v eliminated • rearrangement to give final result Allow ECF for incorrect V expression from (b)(i): for 1st and 2nd marks only (ie max 2).	4	
3(c)(i)	nucleon number = 216		1	
3(c)(ii)	$E_\alpha = \left(\dfrac{216}{220}\right)\times 1.02\times10^{-12}$ **or** $= 1.00 \times 10^{-12}$ (J) ✓ momentum of α = $m\sqrt{\dfrac{2E_\alpha}{m}}$ or = $\sqrt{2mE_\alpha}$ [**or** $\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 1.00 \times 10^{-12}$ gives momentum of α = $4\times1.66\times10^{-27}\times\sqrt{\dfrac{2\times1.00\times10^{-12}}{4\times1.66\times10^{-27}}}$] ✓ $\therefore$ momentum of α = $\sqrt{\left(2\times4\times1.66\times10^{-27}\times1.00\times10^{-12}\right)}$	Allow ECF for wrong value of A from (c)(i). **Alternative solution** for first three marks: energy of nucleus = 0.0185×10^{-12} (J) ✓ momentum of nucleus = $\sqrt{2NE_N}$ ✓ $\sqrt{\left(2\times216\times1.66\times10^{-27}\times0.0185\times10^{-12}\right)}$ = $1.2\ (1.15) \times 10^{-19}$ ✓	4	

	= $1.2\ (1.15) \times 10^{-19}$ ✓ N s **or** kg m s^{-1} ✓	Unit mark is independent.		
3(d)	an (anti)neutrino is emitted OR two particles are emitted by unstable nucleus in β^- decay [**or** calculation must account for momentum of (anti)neutrino] **[or** momentum is shared between three particles] ✓		1	
Total			13	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4(a)	amplitude (of bob) is small [**or** (angular) amplitude is less than or = 10°] [**or** sin $\theta \approx \theta$ with θ explained] ✓	**or** string is inextensible (or of negligible mass) **or** bob is a point mass Ignore references to “air resistance”.	1	
4(b)	**The candidate’s writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate’s answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The candidate describes the arrangement of the apparatus clearly. They identify correctly the measurements to be made, and indicate how these measurements would be made. They describe a valid method by which a straight line graph may be obtained and show how g would be calculated from their graph. They are also aware of precautions that should be taken during the experiment to ensure that the result is accurate.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used	A **high level** answer must include 1. a description of the apparatus, 2. a correct statement of the measurements to be made, 3. a correct graph plot, 4. a correct indication of how g would be found from the graph, 5. at least two precautions. An **intermediate level** answer must include (at least) 1 and 2, **or** 1 and 3, **or** 2 and 3, above and at least one precaution. A **low level** answer must include (at least) any one of 1,2,3,4 above. An inappropriate, irrelevant or physically incorrect answer should be awarded **a mark of zero.** If the experiment described relates to a	max 6	

	incorrectly. The form and style of writing is less appropriate. *The candidate is less clear about the experimental arrangement, gives a reasonable account of the measurements to be made and indicates a valid method by which a straight line graph may be obtained. They are less clear about how the result would be calculated from the graph, and they know the precautions less well.* **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. *The candidate gives a superficial account of the experimental arrangement, has some knowledge of the measurements to be made, but has only limited ability to show how a graphical method could be used to calculate the result. Some precautions may be known.* **The description expected in a competent answer should include a coherent selection of the following points.** • Diagram or description showing a bob suspended from a fixed point, on which the length l may be labelled correctly. • Length l of pendulum measured by ruler from fixed point of support to centre of mass of bob. • Period T measured by stopwatch, by timing a number of oscillations. • Measurement of T repeated for the same l and a mean value of T calculated. • Measurements repeated for at least five different values of l.	**compound pendulum**, mark to max 2. If a log graph is plotted and explained, it may gain credit. If a correct graph is **not** used, then maximum mark awarded is 3.		

	• Graph of T^2 against l (or any other suitable linear graph) would be plotted. • Graph is a straight line through origin, gradient is $4\pi^2/g$ (or correct expression for g from their graph). **Experimental measures such as the following are likely to be given:** • Small amplitude oscillations. • Measure l to centre of mass of bob. • Measure T from a large number of oscillations. • Repeat timing for each length. • Begin counting oscillations at nought when t = 0. • Measure complete oscillations. • Use of fiducial mark at centre of oscillations. • Pendulum should swing in a vertical plane. • Avoid very small values of l when repeating the experiment. **Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.**			
4(c)	measured value of g will be 4× true value of g ✓ gradient of T^2 against l graph will be ¼ of expected value [**or** reference to $g \propto 1/T^2$ or equivalent] ✓ (T is halved so) T^2 is ¼ of true value ✓	2nd and 3rd marks may be covered by an analysis of the period equation.	3	
Total			10	

Question	Answers	Additional Comments/Guidance	Mark	ID details
5(a)	*(Faraday's law)* (induced) emf $\propto$ rate of change of flux (linkage) ✓ *(Lenz's law)* <u>direction of</u> induced emf (or current) ✓ is such as to oppose the change (in flux) producing it ✓	In either order. Allow "(induced) emf = rate of change of *flux linkage*". Ignore incorrect reference to names of laws.	3	
5(b)(i)	current in coil produces magnetic field or flux (that passes through disc) ✓ rotating disc cuts flux inducing/producing emf **or** current (in disc) ✓ induced (eddy) currents (in disc) interact with magnetic field ✓ force on (eddy) currents slows (or opposes) rotation (of disc) ✓	**Alternative** for last two points: (eddy) currents in disc cause heating of disc ✓ energy for heating comes from ke of disc or vehicle (which is slowed) ✓	max 3	
5(b)(ii)	*Advantage:* any one ✓ • no material (eg pads or discs or drums) to wear out • no pads needing replacement • no additional (or fewer) moving parts *Disadvantage:* any one ✓ • ineffective at low speed **or** when stationary • dependent on vehicle's electrical system remaining in working order • requires an electrical circuit (or source of electrical energy) to operate whereas pads do not	Answers must refer to advantages and disadvantages of the *electromagnetic* brake. Only accept points from these lists.	2	
Total			8	