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General Certificate of Education (A-level)
June 2011

Physics A PHYA5/2C

(Specification 2450)

Unit 5/2C: Applied Physics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner 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 examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' 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

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Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	*see specific mark scheme*	**5-6**
Modest - Adequate	*see specific mark scheme*	**3-4**
Poor - Limited	*see specific mark scheme*	**1-2**
The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme*		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.

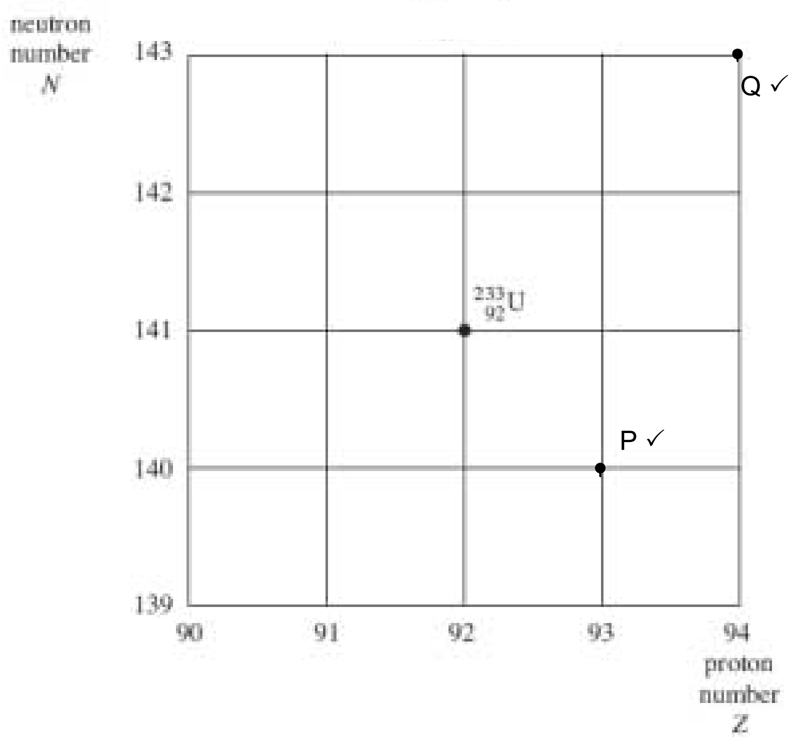
4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

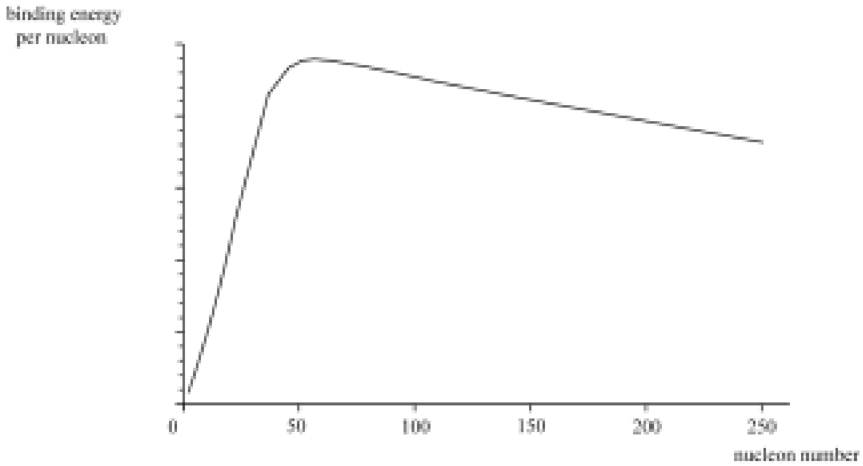
6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

GCE Physics, Specification A, PHYA5/1, Nuclear and Thermal Physics

Question 1		
a	$^{231}_{91}\text{Pa}$ ✓ anti (electron) neutrino ✓	**2**
b		**2**
c i	x = 4 ✓	**1**
c ii	mass defect = [(232.98915 + 1.00867) – (90.90368 + 138.87810 + 4 × 1.00867)] u ✓ = 0.18136 u ✓ energy released (= 0.18136 × 931) = 169 (MeV) ✓	**3**
	Total	**8**

Question 2		
a	$^{27}_{13}\text{Al} + \alpha \rightarrow {}^{30}_{15}\text{P} + {}^{(1)}_{(0)}\text{n}$ ✓	**1**
b	kinetic energy lost by the α particle approaching the nucleus is equal to the potential energy gain ✓ $2.18 \times 10^{-12} = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{13 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}}{r}$ ✓ $r = 2.75 \times 10^{-15}$ (m) ✓	**3**
	Total	**4**

Question 3		
a	 peak 8.7 (accept 8.0 – 9.2) ✓ in MeV ✓ (or peak 1.4×10^{-12} accept $1.3 – 1.5 \times 10^{-12}$ ✓ in J ✓) at nucleon number 50 – 60 ✓ accept 50 – 75 sharp rise from origin and moderate fall not below 2/3 of peak height ✓	**4**
b	energy is released/made available when binding energy **per nucleon** is increased ✓ in fission a (large) nucleus splits and in fusion (small) nuclei join ✓ the most stable nuclei are at a peak ✓ fusion occurs to the left of peak and fission to the right ✓	**max 3**
	Total	**7**

Question 4		
a	(use of $\Delta Q = mc\Delta T$) $30 \times 98 = 0.100 \times c \times 14$ ✓ $c = 2100$ (J kg^{-1} K^{-1}) ✓	**2**
b	(use of $\Delta Q = ml + mc\Delta T$) $500 \times 98 = 0.100 \times 3.3 \times 10^5$ ✓ + $0.100 \times 4200 \times \Delta T$ ✓ (ΔT = 38°C) T = 38°C ✓	**3**
c	the temperature would be higher ✓ as the ice/water spends more time below 25°C **or** heat travels in the direction from hot to cold **or** ice/water first gains heat then loses heat any one line ✓	**2**
	Total	**7**

Question 5		
a	graph passes through given point 2.2×10^{-3} m^3 at 0°C straight line with positive gradient ✓ (straight) line to aim or pass through –273°C at zero volume ✓	**2**
b	(use of $n = PV/RT$) $1.00 \times 10^5 \times 2.20 \times 10^{-3}/8.31 \times 273$ ✓ n = 0.0970 (moles) ✓	**2**
c	(use of mean kinetic energy = 3/2 K T) $= 3/2 \times 1.38 \times 10^{-23} \times 323$ ✓ 6.69×10^{-21} (J) ✓ 3 sfs ✓	**3**
d	total internal energy = $6.69 \times 10^{-21} \times 0.0970 \times 6.02 \times 10^{23}$ = 390 (J) ✓	**1**
e	**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 provides a comprehensive and coherent sequence of ideas linking the motion of molecules to the pressure they exert on a container. At least three of the first four points listed below must be given in a logical order. The description should also show awareness of how a balance is maintained between the increase in speed and shortening of the time interval between collisions with the wall to maintain a constant pressure. To be in this band, reference must be made to force being the rate of change of momentum or how, in detail, the volume compensates for the increase in temperature. **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 incorrectly. The form and style of writing is less appropriate. The candidate provides a comprehensive list of ideas linking the motion of molecules to the pressure they exert on a container. At least three of the first four points listed below are given. The candidate also knows than the mean square speed of molecules is proportional to temperature. Using this knowledge, an attempt is made to explain how the pressure is constant.	**max 6**

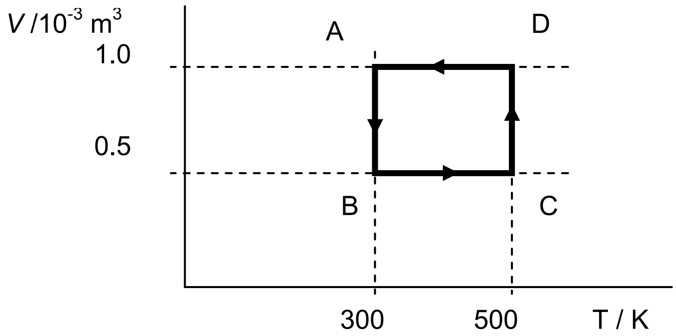
	Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate attempts the question and refers to at least two of the points listed below. **Incorrect, inappropriate of no response: 0 marks** No answer or answer refers to unrelated, incorrect or inappropriate physics. **Statements expected in a competent answer should include some of the following marking points.** molecules are in rapid random motion/many molecules are involved molecules change their momentum or accelerate on collision with the walls reference to Newton's 2nd law either $F = ma$ or F = rate of change of momentum reference to Newton's 3rd law between molecule and wall relate pressure to force $P = F/A$ mean square speed of molecules is proportional to temperature as temperature increases so does change of momentum or change in velocity compensated for by longer time between collisions as the temperature increases as the volume increases the surface area increases which reduces the pressure	
	Total	**14**

GCE Physics, Specification A, PHYA5/2C, Applied Physics

Question 1		
a	the (total) angular momentum (of a system) remains constant provided no external torque acts (on the system) ✓	**1**
b i	(as core radius decreases M of I of core decreases) $I\omega$ must remain constant ✓ I decreases so ω increases and greater ω means shorter period of rotation or less time for one revolution ✓	**2**
b ii	$0.4\, mR_1^2 \times 2\pi/T_1 = 0.4\, mR_2^2 \times 2\pi/T_2$ ✓ $T_2/T_1 = R_2^2/R_1^2$ ✓ $T_2 = \frac{(12 \times 10^3)^2}{(4.1 \times 10^7)^2} \times 3.8 \times 10^6$ = 0.33 s ✓ 2 sf ✓ **or** $0.4\, m \times (4.1 \times 10^7)^2 \times \omega_1$ $= 0.4\, m \times (12 \times 10^3)^2 \times \omega_2$ ✓ $\omega_1 = 2\pi/T = 2\pi/(3.8 \times 10^6) = 1.7 \times 10^{-6}$ rad s^{-1} ✓ (1.65×10^{-6}) leading to $\omega_2 = 20$ rad s^{-1} [19.3 if 1.65×10^{-6} used] $T_2 = 2\pi/\omega_2 = 0.31$ s (2 sf throughout) ✓ 2 sf ✓ [0.33 s if 1.65×10^{-6} rad s^{-1} and 19.3 rad s^{-1} used]	**4**
	Total	**7**

Question 2		
a	**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 provides a comprehensive and logical explanation which recognises that energy stored depends on moment of inertia and ω^2 and that moment of inertia itself depends on the mass and how the mass is distributed about the axis of rotation, quoting and explaining Σmr^2. They will appreciate that a high mass will result from using high density material and they will realise that increasing the radius alone will not necessarily increase M of I for a given mass, but the shape (eg spoked or not) might. They will refer to means of promoting high speed and may appreciate why there is a limit to the maximum speed depending on tensile strength. **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 incorrectly. The form and style of writing is less appropriate. The candidate provides a comprehensive and logical explanation which links moment of inertia and ω^2 to energy stored and will discuss the factors that affect the moment of inertia, but there may be errors in their understanding. They will probably refer to the need to reduce friction but they may not state how this may be done. There may be some reference to the density or strength of the materials used, but the links with energy storage or M of I will be vague. The answer should be adequately or well-presented in terms of spelling, punctuation and grammar. **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 recognises that energy storage depends on speed and M of I, but may not link M of I adequately to radius or mass or the distribution of the mass. They may confuse power or angular momentum with energy. The answer may lack coherence and may contain a significant number of errors in terms of spelling and punctuation. **Incorrect, inappropriate of no response: 0 marks** No answer or answer refers to unrelated, incorrect or inappropriate physics.	**max 6**

		Statements expected in a competent answer should include some of the following marking points. Linking E to ω^2 Linking E to Σmr^2 Importance of shape; put more *m* at greater *r*, use thin axle High density material promotes high *m* for given size Friction reduced by low-friction (eg magnetic- or air-) bearings and smooth outer surface Rotational speed limited by tensile strength of material Reference to centripetal force Frictional torque increases with rotational speed Some answers might refer to adverse gyroscopic effects or need for perfect balance	
b	i	$\Delta E = ½\ I\ (\omega_1^2 – \omega_2^2) = 0.5 \times 0.036 \times (6400^2 – 3100^2) = 560 \times 10^3$ J ✓	**1**
b	ii	$P = E/t = \frac{560 \times 10^3}{6.6} = 85000$ W ✓ accept 85 kW if unit is changed in answer line from W to kW	**1**
b	iii	$T = P/\omega_{ave}\ \frac{85 \times 10^3}{4750}$ ✓ N m ✓ **or** $T = I\ \alpha = 0.036 \times \frac{(6400-3100)}{6.6} = 18$ ✓ N m ✓	**2**
b	iv	$T\theta = \Delta E$ $\theta = 560 \times 10^3/18 = 31 \times 10^3$ rad ✓ $\frac{31 \times 10^3}{2\pi} = 4900$ rev ✓ **or** $\theta = ½\ (6400 + 3100) \times 6.6 = 31 \times 10^3$ rad ✓ = 4900 rev ✓ **or** $\theta = \omega_1 t – ½\ \alpha\ t^2$ $= 6400 \times 6.6 – ½\ 500 \times 6.6^2 = 31 \times 10^3$ rad ✓ = 4900 rev ✓	**2**
		Total	**12**

Question 3			
a	i	use of PV/T = constant $\frac{P_D V_D T_A}{P_A V_A}$ ✓ $= \frac{2.5 \times 1.0 \times 300}{1.5 \times 1.0}$ ✓ = 500 K	**2**
a	ii	$Q = \Delta U + W$ $\Delta U = 0$ ✓ $Q = W = 173$ J ✓	**2**
b	i	work out = 173 – 104 = 69 J ✓	**1**
b	ii	efficiency = 69/173 = 0.40 or 40% ✓ $\eta_{max} = (T_H - T_C)/T_H$ = (500 – 300)/500 = 0.39 or 40% ✓	**2**
c		 rectangle in correct position ✓ letters correct place ✓ (arrows optional)	**2**
d		• isothermal process impossible unless very slow or via perfect conductor • engine would have to stop for constant volume processes to take place • regenerator would lose heat to surroundings (unless perfectly insulated) • long time needed for heat to transfer from regenerator to working fluid • regenerator would need to be very large/large surface area for heat transfer to take place quickly accept other sensible suggestions **do not** accept 'heat loss to surroundings' or 'friction' any two ✓✓	**2**
		Total	**11**

Question 4			
a	i	3.2 × 780 = 2500 W ✓	1
a	ii	2500 – Q_{out} = 780 Q_{out} = 1720 W ✓ **or** 3.2 = $\frac{Q_{in}}{Q_{in} - Q_{out}} = \frac{2500}{2500 - Q_{out}}$ giving Q_{out} = 1720 W ✓	1
b		• heat pump does deliver more energy than is input as work on the system but there must also be energy input from cold space ✓ • obeys conservation of energy because work done plus energy from cold space (or equivalent, eg ground) equals energy by heat transfer to hot space (or equivalent) ✓ • obeys second law because (reversed heat engine) operates between hot and cold spaces [accept 'source' and 'sink'] ✓ • work done on the system requires energy transfer (from a heat engine elsewhere) so overall result is spreading out of energy [owtte] ✓	max 3
		Total	**5**

	UMS conversion calculator www.aqa.org.uk/umsconversion	