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General Certificate of Education (A-level)
June 2011

Physics A PHYA5/2D

(Specification 2450)

Unit 5/2D: Turning Points in 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.

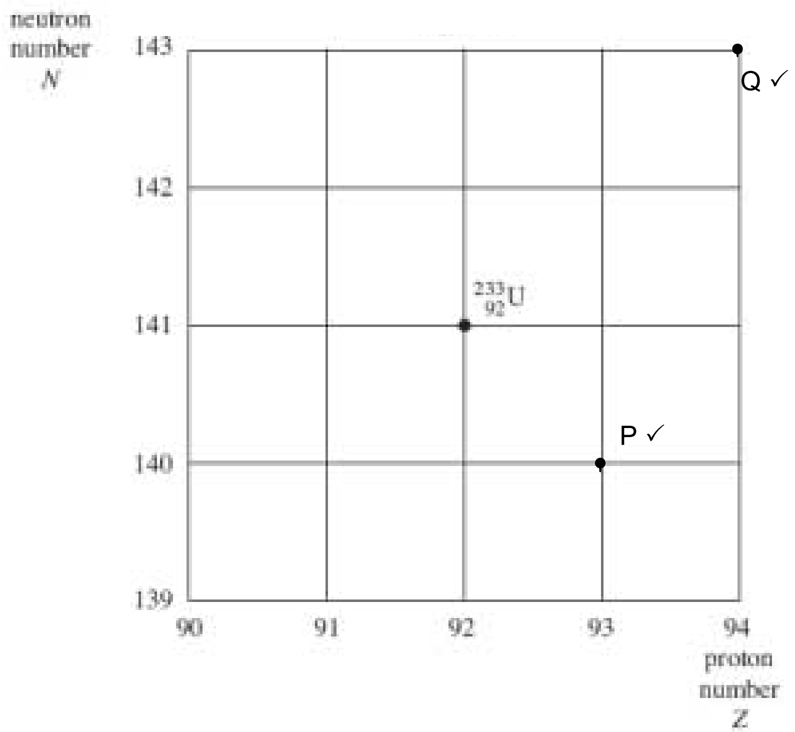
4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other 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.

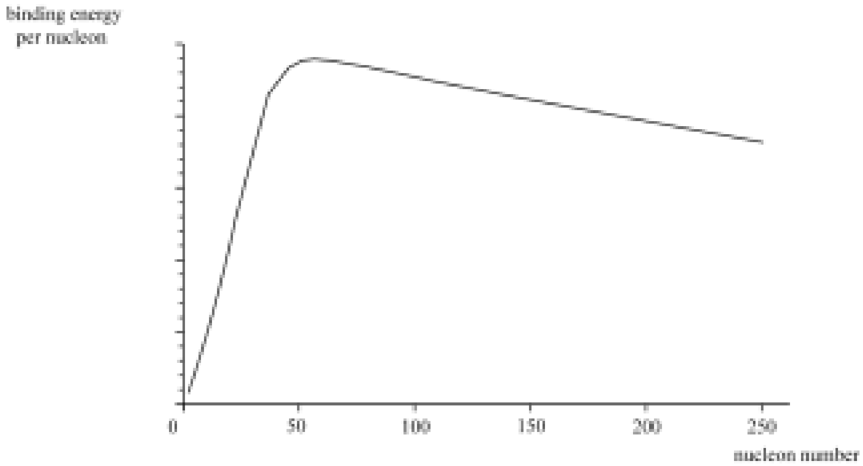
6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. 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	$^{231}_{91}\mathrm{Pa}$ ✓ 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	$^{27}_{13}\mathrm{Al} + \alpha \rightarrow {}^{30}_{15}\mathrm{P} + {}^{(1)}_{(0)}\mathrm{n}$ ✓	**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 × 98 = 0.100 × c × 14 ✓ c = 2100 (J kg^{-1} K^{-1}) ✓	**2**
b	(use of $\Delta Q = ml + mc\Delta T$) 500 × 98 = 0.100 × 3.3 × 10^5 ✓ + 0.100 × 4200 × ΔT ✓ (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 $n = P\ V/R\ T$) $1.00 \times 10^5 \times 2.20 \times 10^{-3}/8.31 \times 273$ ✓ 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, PHYA5/2D, Turning Points in Physics

Question 1		
a i	diffraction ✓	**1**
a ii	the electrons in the beam must have the same wavelength ✓ otherwise electrons of different wavelengths (or speeds/velocities/energies/ momenta) would diffract by different amounts (for the same order) [owtte] ✓	**2**
b i	($eV = ½ mv^2$ gives) **either** $v = \sqrt{\frac{2eV}{m}}$ **or** $1.6 \times 10^{-19} \times 25000 = ½ \times 9.1 \times 10^{-31} \times v^2$ ✓ $v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 25000}{9.1 \times 10^{-31}}} = 9.4 \times 10^7\ \text{m s}^{-1}$ ✓ p or mv (= $9.1 \times 10^{-31} \times 9.4 \times 10^7$) = 8.5×10^{-23} ✓ kg m s^{-1} (or N s) ✓ **alternatives for first two marks** p or $mv = \sqrt{2meV}$ ✓ = $\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 25000}$ ✓	**4**
b ii	**any two of the first three mark points** increase of pd increases the speed (or velocity/energy/momentum) of the electrons ✓ (so) the electron wavelength would be smaller ✓ (and) the electrons would diffract less (when they pass through the lenses) ✓ **and** the image would show greater resolution (or be more detailed) ✓	**max 3**
	Total	**10**

Question 2		
a i	**either** (at terminal speed (*v*)) the viscous force on the droplet = its weight (or *mg* or the force of gravity on it) **or** viscous force = $6\pi\eta rv$ (where r is the radius of the droplet and η is its viscosity) and weight (= mg) = $4\pi r^3 \rho g/3$ ✓ $4\pi r^3 \rho g/3 = 6\pi\eta rv$ ✓ (which gives $r = (9\eta v/2\rho g)^{½}$)	2
a ii	*r* (can be calculated as above then) used in the formula $m = 4\pi r^3 \rho/3$ to find the droplet mess, *m* [owtte] ✓ **alternatively**; (from $6\pi\eta rv = mg$) (as all values are known use) $m = 6\pi\eta rv/g$ ✓	1
b i	electric force (or *QV*/*d*) = the droplet weight (or *mg*) ✓ $Q = \frac{mgd}{V} = \frac{6.8 \times 10^{-15} \times 9.8\ (1) \times 5.0 \times 10^{-3}}{690} = 4.8 \times 10^{-19}$ C ✓ 2 sf answer ✓	3
b ii	**any two from** the charge on each droplet is a whole number × 1.6×10^{-19} C (or × charge of the electron) ✓ the least amount of charge (or the quantum of charge) is the charge of the electron ✓ the quantum of charge is 1.6×10^{-19} C [owtte] ✓	max 2
	Total	**8**

Question 3		
a i	Newton's other theories were successful (or Newton was more eminent so Newton's view was accepted) ✓ **alternatives**, Huygens' theory was based on longitudinal waves which can not explain polarisation **or** Huygens' theory could not explain sharp shadows	1
a ii	**either** Newton predicted that light travels faster in glass than in air, Huygens' predicted the opposite ✓ **or** there was no evidence (for many years) that light travels slower or faster in glass than in air ✓ the speed of light in water (or glass) was (eventually) found to be less than the speed of light in air ✓ diffraction/interference observations not conclusive ✓	max 2

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 provides a comprehensive, coherent and logical explanation which recognises that the pattern is due to interference of light which is a wave property. They should know that at a bright fringe, the waves from the two slits are in phase and therefore reinforce each other and this can happen at positions where the path difference is zero or a whole number of wavelengths. They may not refer to the need for the waves to be coherent. Their answer should be well-presented in terms of spelling, punctuation and grammar. **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 logical explanation which recognises that interference of light is a wave property. They should know either a bright fringe is where the waves from the two slits are in phase or a dark fringe is where they are out of phase by 180° and be aware there are different positions where these conditions apply. They may know the general condition for the path difference for a bright fringe or a dark fringe although they may not recognise that this condition explains why there are more than two bright fringes. Their 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 interference of light is a wave property and that the waves from the two slits reinforce at a bright fringe or cancel at a dark fringe. They may confuse path difference and phase difference and their explanation of why there are more than two bright fringes may be vague or absent. Their 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. the pattern is due to interference of light from the two slits interference is a wave property light from the two slits is in phase at a bright fringe and therefore reinforces the path difference (from the central bright fringe to the two slits) is zero **either** bright fringes are formed away from the centre wherever the path difference is a whole number of wavelengths **or** dark fringes are formed away from the centre wherever the path difference is a whole number of wavelengths + a half wavelength the path difference for the m^{th} bright fringe from the centre is m wavelengths where m is any whole number since m is any whole number, more than two bright fringes are observed	
	Total	**9**

Question 4		
a i	d_0 =(speed × time = $1.8 \times 10^8 \times 95 \times 10^{-9}$) = 17(.1) m ✓	**1**
a ii	d (= $d_0 (1 - v^2/c^2)^{½}$) = $17.1 \times (1 - (1.8 \times 10^8/3.0 \times 10^8)^2))^{½}$ ✓ = 14 m ✓ (or 13.7 m or 13.68 m) **or** $t = t_0 (1 - v^2/c^2)^{-½}$ $95 = t_0 \times (1 - (1.8 \times 10^8/3.0 \times 10^8)^2)^{-½}$ gives t_0 = 76 ns ✓ $d = vt_0 = 1.8 \times 10^8 \times 76 \times 10^{-9}$ = 14 m ✓ (or 13.7 m or 13.68 m)	**2**
b	m (= $m_0 (1 - v^2/c^2)^{-½}$) = $1.67(3) \times 10^{-27} \times (1 - (1.8 \times 10^8/3.0 \times 10^8)^2)^{-½}$) ✓ = 2.09×10^{-27} kg ✓ kinetic energy = $(m - m_0)\, c^2$ **or** correct calculation of $E = mc^2$ (= 1.88×10^{-10} J) **or** correct calculation of $E_0 = m_0c^2$ (= 1.50×10^{-10} J)✓ $\frac{\text{kinetic energy}}{\text{rest energy}} = \frac{(m - m_0)c^2}{m_0c^2} = \frac{(2.09 - 1.67) \times 10^{-27}}{1.67 \times 10^{-27}}$ ✓ = 0.25 (allow 0.245 to 0.255 or ¼ or 1:4) ✓	**5**
	Total	**8**

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