Version 1.0

General Certificate of Education (A-level)
June 2012

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

1	a		$\Delta T = (\frac{\Delta Q}{mc} =)\ \frac{8.5 \times 10^3}{4200 \times 0.12}$ ✓ 17 K ✓	2
1	b		$\left(\frac{\Delta T}{\Delta t} = \frac{\frac{\Delta Q}{\Delta t}}{mc}\right) = \frac{100-26}{\Delta t} = \frac{8.5 \times 10^3}{0.41 \times 4200}$ ✓ t = 15 s ✓	2
2	a		$({}^{206}_{76}\mathrm{X} \rightarrow {}^{206}_{82}\mathrm{Pb} + \beta \times {}^{0}_{-1}\beta + \beta \times \overline{\nu_e})$ β = 6 ✓	1
2	b	i	the energy **required** to split up the nucleus ✓ into its individual neutrons and protons/nucleons ✓ (or the energy **released** to form/hold the nucleus ✓ from its individual neutrons and protons/nucleons ✓)	2
2	b	ii	7.88 × 206 = 1620 MeV ✓ (allow 1600-1640 MeV)	1
2	c	i	U, a graph starting at 3×10^{22} showing exponential fall passing through 0.75×10^{22} near 9×10^9 years ✓ Pb, inverted graph of the above so that the graphs cross at 1.5×10^{22} near 4.5×10^9 years ✓	2
2	c	ii	(*u* represents the number of uranium atoms then) $\frac{u}{3 \times 10^{22} - u} = 2$ $u = 6 \times 10^{22} - 2u$ ✓ $u = 2 \times 10^{22}$ atoms	1
2	c	iii	(use of $N = N_o e^{-\lambda t}$) $2 \times 10^{22} = 3 \times 10^{22} \times e^{-\lambda t}$ ✓ $t = \ln 1.5 / \lambda$ (use of $\lambda = \ln 2 / t_{1/2}$) $\lambda = \ln 2 / 4.5 \times 10^9 = 1.54 \times 10^{-10}$ ✓ $t = 2.6 \times 10^9$ years ✓(or 2.7×10^9 years)	3
3	a		any 2 from: the sun, cosmic rays, radon (in atmosphere), nuclear fallout (from previous weapon testing) , any radioactive leak(may be given by name of incident) nuclear waste, carbon-14 ✓	1

3	b	i	(ratio of area of detector to surface area of sphere) ratio = $\frac{0.0015}{4\pi(0.18)^2}$ ✓ 0.0037 ✓ (0.00368)	2
3	b	ii	activity = 0.62/(0.00368 × 1/400) give first mark if either factor is used. 67000 ✓ Bq accept s^{-1} or decay/photons/disintegrations s^{-1} but not counts s^{-1}✓ (67400 Bq)	3
3	c		(use of the inverse square law) $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$ or calculating k = 0.020 from $I = k/x^2$ ✓ $I_2 = 0.62 \times \left(\frac{0.18}{0.28}\right)^2$ ✓ 0.26 counts s^{-1} ✓(allow 0.24-0.26)	3
4	a	i	$n = PV/RT = 3.2 \times 10^5 \times 1.9 \times 10^{-3}/8.31 \times 285$ *n* = 0.26 mol ✓ (0.257 mol)	1
4	a	ii	$P_2 = \frac{T_2}{T_1} \times P_1 = \frac{295}{285} \times 3.20 \times 10^5$ ✓ 3.31×10^5 Pa ✓(allow 3.30-3.35 × 10^5 Pa) 3 sig figs ✓sig fig mark stands alone even with incorrect answer	3
4	b		similar -(rapid) **random** motion - range of speeds different - **mean** kinetic energy - root **mean** square speed - **frequency** of collisions	2
5	a		graph starting (steeply) near/at the origin and decreasing in gradient ✓	1
5	b	i	(use of density = mass/volume) $\frac{197 \times 1.67 \times 10^{-27}}{\frac{4}{3}\pi\,(6.87 \times 10^{-15})^3}$ ✓✓mark for top line and mark for bottom line (allow use of 1.66 x 10^{-27}) Lose mass line mark if reference is made to mass of electrons = 2.4(2) × 10^{17} kg m^{-3}	2

5	b	ii	$R_{A1} = R_{Au}\left(\frac{A_{A1}}{A_{Au}}\right)^{\frac{1}{3}} = 6.87 \times 10^{-15}\left(\frac{27}{197}\right)^{\frac{1}{3}}$ ✓ = 3.54×10^{-15} m ✓ or $r_0 = \frac{R}{A^{\frac{1}{3}}} = \frac{6.87 \times 10^{-15}}{197^{\frac{1}{3}}} = 1.18 \times 10^{-15}$ m ✓ $R = 1.18 \times 10^{-15} \times 27^{\frac{1}{3}} = 3.54 \times 10^{-15}$ m ✓ or volume = mass/density = $\frac{27 \times 1.67 \times 10^{-27}}{2.42 \times 10^{17}} = \frac{4}{3}\pi \times R^3$ ✓ = 3.54×10^{-15} m ✓	2

5	c		**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 makes 5 to 6 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method* **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 makes 3 to 4 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method* **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 makes 1 to 2 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method*	max 6

			The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences. **principles** • α scattering involves coulomb or electrostatic repulsion • electron diffraction treats the electron as a wave having a de Broglie wavelength • some reference to an equation, for example $\lambda = h/mv$; $eV = mv^2/2$; $Qq/4\pi\varepsilon_o r = E_\alpha$; $\sin\theta = 0.61\lambda/R$ • reference to first minimum for electron diffraction **accuracy** • α's only measure the least distance of approach, not the radius • α's have a finite size which must be taken into account • electrons need to have high speed/kinetic energy • to have a small wavelength or wavelength comparable to nuclear diameter, the wavelength determines the resolution • the wavelength needs to be of the same order as the nuclear diameter for significant diffraction • requirement to have a small collision region in order to measure the scattering angle accurately • importance in obtaining monoenergetic beams • cannot detect alpha particles with exactly 180^o scattering • need for a thin sample to prevent multiple scattering **advantages and disadvantages** • α-particle measurements are disturbed by the nuclear recoil • Mark for α-particle measurements are disturbed by the SNF when coming close to the nucleus or electrons are not subject to the strong nuclear force. • A second mark can be given for reference to SNF if they add electrons are leptons or alpha particles are hadrons. • α's are scattered only by the protons and not all the nucleons that make up the nucleus • visibility – the first minimum of the electron diffraction is often difficult to determine as it superposes on other scattering events	

GCE Physics, Specification A, PHYA5/2D, Turning Points in Physics

1	a		force due to electric field acts (vertically) downwards on electrons ✓ vertical (component) of velocity of each electron increases ✓ horizontal (component of) velocity unchanged (so angle to initial direction increases ✓	3
1	b	i	magnetic flux density should be reversed and adjusted in strength (gradually until the beam is undeflected) ✓	1
1	b	ii	magnetic (field) force = Bev and electric (field) force = eV / d ✓ (Accept Q or q as symbol for e (charge of electron) $Bev = eV/d$ (for no deflection) gives $v = V / Bd$ ✓	2
1	c		(gain of) kinetic energy of electron = work done by anode pd or $\frac{1}{2} m v^2 = e V_{(A)}$ ✓ $\frac{e}{m}\left(= \frac{v^2}{2 V_{(A)}}\right) = \frac{(3.9 \times 10^7)^2}{2 \times 4200}$ ✓ $= 1.8 \times 10^{11}$ C kg^{-1} ✓	3
2	a		(vibrations of) the electric wave and magnetic wave; perpendicular to each other ✓ perpendicular to direction of propagation ✓ in phase with each other ✓	3
2	b		μ_o and ε_o determined experimentally (or μ_o and ε_o values were known) ✓ (substitution of values of μ_o and ε_o into) predicted equation gives 3(.0) × 10^8 m s^{-1} (or the speed of light)✓ which is the speed of light (or 3(.0) × 10^8 m s^{-1}) ✓	max 2
2	c	i	magnetic wave vibrations perpendicular to (plane of) loop ✓ (magnetic wave) causes alternating (or changing) magnetic flux (linkage or cutting) through the loop ✓ alternating magnetic flux (or field) induces an alternating (or changing) emf (or pd) in the loop ✓ [**or** equivalent E-field statements E-wave (or field) vibrations parallel to loop ✓ E-wave (or field) induces emf (or pd) in wire of loop ✓ E-wave (or field) alternates so induced emf is alternating ✓]	3

2	c	ii	no magnetic flux (linkage or cutting) through the loop (as loop is now parallel to magnetic wave vibrations) so no induced emf (or pd) ✓ (**or** electric field perpendicular to loop so no induced emf (or pd) ✓)	1

3	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 coherent answer that includes a stated property of light such as interference or diffraction that can only be explained in terms of the wave nature of light and a <u>stated property</u> such as photoelectricity that can only be explained in terms of the particle nature of light. In each case, a relevant specific <u>observational feature</u> should be referred to and should be accompanied by a <u>coherent explanation</u> of the observation. Both explanations should be relevant and <u>logical</u>.* *For full marks, the candidate may show some appreciation as to why the specific feature of either the named wave property cannot be explained using the particle nature of light or the named particle property cannot be explained using the wave nature of light.* **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 and coherent explanation that includes a stated property of light such as interference or diffraction that can only be explained in terms of the wave nature of light* ***and*** *a stated property such as photoelectricity that can only be explained in terms of the particle nature of light.* *For 4 marks, the candidate should be able to refer to a relevant specific observational feature of each property, at least one of which should be followed by an adequate explanation of the observation. Candidates who fail to refer to a relevant specific observational feature for one of the properties may be able to score 3 marks by providing an <u>adequate</u> explanation of the observational feature referred to.*	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 provides some relevant information relating to two relevant stated properties for 1 mark. Their answer may lack coherence and may well introduce irrelevant or incorrect physics ideas in their explanation.* **Points that can be used to support the explanation:** **Wave-like nature property** • property is either interference **or** diffraction • observational feature is either the bright and dark fringes of a double slit interference pattern or of the single slit diffraction pattern (or the spectra of a diffraction grating) • explanation of bright or dark fringes (or explanation of diffraction grating spectra) in terms of path or phase difference • particle/corpuscular theory predicts two bright fringes for double slits or a single bright fringe for single slit or no diffraction for a diffraction grating **Particle-like nature** • property is photoelectricity • observational feature is the existence of the threshold frequency for the incident light **or** instant emission of electrons from the metal surface • explanation of above using the photon theory including reference to photon energy *hf,* the work function of the metal and '1 photon being absorbed by 1 electron' • wave theory predicts emission at all light frequencies **or** delayed emission for (very) low intensity	

3	b	i	$m\ (= m_o (1 - v^2 / c^2)^{-0.5} = 9.11 \times 10^{-31} (1 - 0.890^2)^{-0.5})$ $(= 1.998 \times 10^{-30}$ kg$) = 2.0(00) \times 10^{-30}$ kg ✓ $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{2.0(0) \times 10^{-30} \times 0.89(0) \times 3.0(0) \times 10^{8}}$ ✓ $(= 1.2(4) \times 10^{-12}$ m$)$	2

3	b	ii	$E_{Ph} = \left(hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{1.24 \times 10^{-12}}\right) = 1.6(0) \times 10^{-13}$ J ✓	1

3	b	iii	$E_K = (m - m_o)\, c^2$ $= (1.998 \times 10^{-30} - 9.11 \times 10^{-31}) \times (3.0 \times 10^{8})^2$ $= 9.78 \times 10^{-14}$ J ✓ 3 sf only ✓	2

4	a		bright (or dark) fringe is seen where the two beams are in phase (or out of phase by 180°) ✓ changing the distance to either mirror changes the path (or phase) difference (between the two beams) so fringes shift ✓	2
4	b	i	speed of light was thought to depend on the speed of the light source (or the speed of the observer) ✓ (or on the motion of the Earth (through the aether)) distance travelled by each beam unchanged (by rotation)✓ time difference between the two beams would change on rotation ✓ phase difference would therefore change (so fringes would shift) ✓	max 3
4	b	ii	speed of light is independent of the speed (or motion) of the light source (or the observer) ✓ (or 'aether' hypothesis incorrect (owtte)) or absolute motion does not exist)	1

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