Version 1.0

General Certificate of Education (A-level)
June 2012

Physics A PHYA5/2B

(Specification 2450)

Unit 5/2B: Medical 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

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

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		$\Delta T = (\frac{\Delta Q}{mc} =)\ \frac{8.5\times10^3}{4200\times0.12}$ ✓ 17 K ✓	2
1	b		$\left(\frac{\Delta T}{\Delta t} = \frac{\frac{\Delta Q}{\Delta t}}{mc}\right) = \frac{100-26}{\Delta t} = \frac{8.5\times10^3}{0.41\times4200}$ ✓ t = 15 s ✓	2
2	a		$({}^{206}_{76}\text{X} \rightarrow {}^{206}_{82}\text{Pb} + \beta \times {}^{0}_{-1}\beta + \beta \times \overline{\nu_e})$ 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) $\frac{u}{3\times10^{22} - u} = 2$ $u = 6 \times 10^{22} - 2u$ ✓ $u = 2 \times 10^{22}$ 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 1.66×10^{-27}) Lose mass line mark if reference is made to mass of electrons $= 2.4(2) \times 10^{17}$ 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, PHYA5/2B, Medical Physics

1	a	i	Ciliary muscles contract / suspensory ligaments relax Producing a lens of greater power / shorter focal length	2
1	a	ii	(Iris circular muscles contract and /or radial muscles relax produces) constricted pupil /pupil becomes smaller Cones turn on and rods become inactive	2
1	b		Colours seen in bright light, but black and white in very dim light Good detail in bright light, but much less detail in very dim light	2
1	c	i	Image is focussed in a given plane and out of focus in **perpendicular** plane	1
1	c	ii	non-spherical cornea	1
1	c	iii	cylindrical lens	1
2	a	i	Reading would be 60dBA as 1kHz is the reference frequency (at the threshold of hearing).	1
2	a	ii	dB reading would be 60dB as power is the same/not frequency dependent. dBA reading would be less than 60 as 500Hz has a higher threshold intensity / ear is less sensitive.	2
2	b		Intensity at meter = 2/(4xπx5x5) (=6.37 x 10^{-3}) Intensity reading = 10 log((2/(4xπx5x5))/1.0 x10^{-12}) Intensity reading = 98 dB Allow ecf here from intensity calc. to get a 'correct' answer: Use of 2 as intensity gains 0 for 123dB Use of 2/5 as intensity gains 1 for 116dB or any use of 2 and a power of 5 **multiplied** also for 1 mark. Use of $2/5^2$ as intensity gains 2 for 109dB or use of $2/\pi 5^2$ gains 2 marks	3
3	a		horizontal line from A to B at 1.5 Vertical line at B from 1.5 to value between 1.5 and 1.4 and then horizontal line from B to C Vertical line at C from value to 1.0 (if possible) and then horizontal line from C to D	3

3	b		Use of non-coherent to transmit light into body/ provide illumination Use of coherent to transmit image/ light to form an image (from inside to viewer/camera)	2

4	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 answer will discuss the multi-array of transducers in a linear formation and the use of gel between the skin and the probe will be explained. There will be mention of the transducers acting as receivers and why ultra sound echoes occur. There will be some discussion of the processing of the received signal to produce an image. The fact that this is non-ionising and thus has no known side effects will be included. **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 answer will contain at least one property of the probe and either the use of gel or the transducer acting as a receiver should be discussed. The processing of the signal will be sketchy, but the reason that ultrasound is safe is likely to be mentioned. **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. There will be a few of the guidance points mentioned, but there will be little cohesion in the writing.	**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 in this case. *Method of obtaining the image* Ultra sound reflected at interface between two different acoustic impedances Each transducer emits pulse in turn and receives the echoes from the interfaces directly in line with it Each echo displayed as a bright spot on screen The brightness is determined by the intensity of the echo The y position is determined by the time taken from transmission to the time of the echo The x position is determined by the position of the transducer Images are produces at about 25 per second and thus appear as a real time moving image *Practical considerations* Probe has line of transducers (approx 100) High frequency ac pulse applied to each transducer in turn Each transducer has piezoelectric crystal to generate ultra sound Use of gel between probe and skin to eliminate air Transducer acts as receiver *Safety* No harmful side effects known – does not use ionising radiation. **Always allow details of other correct probes.**	

4	b		The transducer to be damped/stop oscillating before the echo returns to allow the transducer to act as a receiver. (This time is very short) as distances travelled are short Emitted pulse must cease before echo arrives so that there is no overlapping at the transducer/ no interference	3

5	a	i	$1.60 \times 10^{-19} \times 72.5 \times 10^{3} = 1.16 \times 10^{-14}$ (J) Sig Fig mark for 3sf	2

5	a	ii	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8})/1.16 \times 10^{-14}$ $= 1.71 \times 10^{-11}$ (m)	2

5	b		Narrow beam of X-rays X ray generator rotated(in circular path) around patient Detectors arranged around outside of the path Detector opposite generator registers transmitted intensity Detectors connected to computer which (over time) produces cross sectional image Any **three** relevant points.	Max 3

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