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Physics A PHA5B

(Specification 2450)

Unit 5B: Nuclear and Thermal Physics

Medical Physics

Final

Mark Scheme

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Section A – Nuclear and Thermal Physics

Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)	(i)	1/12 the mass of an (atom) of $^{12}_{6}\mathrm{C}$ / carbon-12 / C12✓	1	a reference to a nucleus loses the mark
1	(a)	(ii)	separated nucleons have a greater mass ✓ (than when inside a nucleus) because of the (binding) energy <u>added</u> to <u>separate</u> the nucleons or energy is <u>released</u> when a nucleus is <u>formed</u> (owtte) ✓	2	an answer starting with 'its' implies the nucleus marks are independent direction of energy flow or work done must be explicit
1	(b)		nuclei need to be <u>close together</u> (owtte) for the Strong Nuclear Force to be involved or for fusion to take place✓ but the electrostatic/electromagnetic force is repulsive (and tries to prevent this) ✓ (if the temperature is high then) the nuclei have (high) kinetic energy/speed (to overcome the repulsion) ✓	3	e.g. first mark – within the range of the SNF 3rd mark is for a simple link between temperature and speed/KE
1	(c)	(i)	15 ✓ e^{+} ✓ (or β^{+}, $^{0}_{1}\beta$, $^{0}_{1}\mathrm{e}$) 12 ✓	3	give the middle mark easily for any e or β with a + in any position

1	(c)	(ii)	Δmass = 4 × 1.00728 – 4.00150 – (2 × 9.11 × 10^{-31}/1.661 × 10^{-27}) or Δmass = {4 × 1.00728 – 4.00150 – 2 × 0.00055}(u) ✓ Δmass = 0.02652(u) ✓ Δbinding energy (= 0.02652 × 931.5) {allow 931.3} Δbinding energy = 24.7 MeV ✓	3	(4×1.00728=4.02912) 1st mark – correct subtractions in any consistent unit. use of m_p = 1.67 × 10^{-27} kg will gain this mark but will not gain the 2nd as it will not produce an accurate enough result 2nd mark – for calculated value 0.02652u 4.405 × 10^{-29} kg 3.364 × 10^{-12} J 3rd mark – conversion to Mev conversion mark stands alone award 3 marks for answer provided some working shown – no working gets 2 marks (2sf expected)
2	(a)		insert control rods (further) into the nuclear core/reactor ✓ which will absorb (more) neutrons (reducing further fission reactions) ✓	2	a change must be implied for 2 marks marks by use of (further) or (more) allow answers that discuss shut down as well as power reduction If a statement is made that is wrong but not asked for limit the score to 1 mark (e.g. wrong reference to moderator)
2	(b)		fission fragments/daughter products or spent/used fuel/uranium rods (allow) plutonium (produced from U-238) ✓	1	not uranium on its own
2	(c)	(i)	γ (electromagnetic radiation is emitted) ✓ as the energy gaps are large (in a nucleus) as the nucleus de-excites down discrete energy levels to allow the nucleus to get to the ground level/state ✓ mark for reason	2	A reference to α or β loses this first mark 2nd mark must imply energy levels or states

2	(c)	(ii)	momentum/kinetic energy is transferred (to the moderator atoms) or a neutron slows down/loses kinetic energy (with each collision) ✓ (eventually) reaching speeds associated with thermal random motion or reaches speeds which can cause fission (owtte)✓	2	

3		(i)	(heat supplied by glass = heat gained by cola) (use of $m_g\, c_g\, \Delta T_g = m_c\, c_c\, \Delta T_c$) $0.250 \times 840 \times (30.0 - T_f) = 0.200 \times 4190 \times (T_f - 3.0)$ ✓ ($210 \times 30 - 210\, t_f = 838\, T_f - 838 \times 3$) $T_f = 8.4(1)$ (°C) ✓	2	1st mark for RHS or LHS of substituted equation 2nd mark for 8.4°C Alternatives: 8°C is substituted into equation (on either side shown will get mark)✓ resulting in 4620J~4190J ✓ or 8°C substituted into LHS ✓ (produces ΔT = 5.5°C and hence) = 8.5°C ~ 8°C ✓ 8°C substituted into RHS✓ (produces ΔT = 20°C and hence) = 10°C ~ 8°C ✓

3		(ii)	(heat gained by ice = heat lost by glass + heat lost by cola) (heat gained by ice = $mc\Delta T + ml$) heat gained by ice = $m \times 4190 \times 3.0 + m \times 3.34 \times 10^5$ ✓ (heat gained by ice = m × 346600) heat lost by glass + heat lost by cola = 0.250 × 840 × (8.41 – 3.0) + 0.200 × 4190 × (8.41 – 3.0) ✓ (= 5670 J) m (=5670/346600) = 0.016 (kg) ✓ or (using cola returning to its original temperature) (heat supplied by glass = heat gained by ice) (heat gained by glass = 0.250 × 840 × (30.0 – 3.0)) heat gained by glass = 5670 (J) ✓ (heat used by ice = $mc\Delta T + ml$) heat used by ice = $m(4190 \times 3.0 + 3.34 \times 10^5)$ ✓ (= m(346600)) m (=5670/346600) = 0.016 (kg) ✓	3	NB correct answer does not necessarily get full marks 3rd mark is only given if the previous 2 marks are awarded (especially look for $m \times 4190 \times 3.0$) the first two marks are given for the formation of the substituted equation not the calculated values if 8^{o}C is used the final answer is 0.015 kg
4	(a)		molecules have negligible volume collisions are elastic the gas cannot be liquified there are no interactions between molecules (except during collisions) the gas obeys the (ideal) gas law / obeys Boyles law etc. at all temperatures/pressures any two lines ✓✓	2	a gas laws may be given as a formula
4	(b)	(i)	n (= PV / RT) = $1.60 \times 10^6 \times 0.200 / (8.31 \times (273 + 22))$ ✓ = 130 or 131 mol ✓ (130.5 mol)	2	

4	(b)	(ii)	mass = 130.5 × 0.043 = 5.6 (kg) ✓ (5.61kg) density (= mass/volume) = 5.61 / 0.200 = 28 ✓ (28.1 kg m^{-3}) kg m^{-3} ✓	3	allow ecf from bi a numerical answer without working can gain the first two marks

4	(b)	(iii)	($V_2 = P_1 V_1 T_2 / P_2 T_1$) V_2 = 1.6 × 10^6 × .200 × (273 – 50) / 3.6 × 10^4 × (273 + 22) or 6.7(2) (m^3)✓ mass remaining = 5.61 × 0.20 / 6.72 = 0.17 (kg) ✓ (0.167 kg) or n = (PV / RT = 3.6 × 10^4 × 0.200 / (8.31 × (273 - 50)) = 3.88(5) (mol) ✓ mass remaining = 3.885 × 4.3 × 10^{-2} = 0.17 (kg) ✓ 2 sig figs ✓	3	allow ecf from bii **[reminder must see bii]** look out for any 2 sf answer gets the mark

5		The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).		
	QWC	**Descriptor**	**Mark range**	
	High Level (Good to excellent)	The candidate refers to all the necessary apparatus and records the count-rate at various distances (or thicknesses of absorber). The background is accounted for and a safety precaution is taken. The presence of an α source is deduced from the rapid fall in the count rate at 2 – 5 cm in air. The presence of a γ source is deduced from the existence of a count-rate above background beyond 30 -50 cm in air (or a range in any absorber greater than that of beta particles, e.g. 3 – 6 mm in Al) or from the intensity in air falling as an inverse square of distance or from an exponential fall with the thickness of a material e.g. lead. *The information should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.*	5-6	If more than one source is used or a different experiment than the question set is answered limit the mark to 4

	Intermediate Level (Modest to adequate)	The candidate refers to all the necessary apparatus and records the count-rate at different distances (or thicknesses of absorber). A safety precaution is stated. The presence of an α source is deduced from the rapid fall in the count rate at 2 – 5 cm in air and the γ source is deduced from the existence of a count-rate beyond 30 -50 cm in air (or appropriate range in any absorber, e.g. 3 -6 mm in Al). Some safety aspect is described. One other aspect of the experiment is given such as the background. *The grammar and spelling may have a few shortcomings but the ideas must be clear.*	3-4	To get an idea of where to place candidate look for 6 items: 1.Background which must be used in some way either for a comparison or subtracted appropriately 2.Recording some data with a named instrument
	Low Level (Poor to limited)	The candidate describes recording some results at different distances (or thicknesses of absorber) and gives some indication of how the presence of α or γ may be deduced from their range. Some attempt is made to cover another aspect of the experiment, which might be safety or background. *There may be many grammatical and spelling errors and the information may be poorly organised.*	1 - 2	3.Safety reference appropriate to a school setting – not lead lined gown for example 4.Record data with more than one absorber or distances 5.α source determined from results taken 6.γ source determined
		The description expected in a competent answer should include a coherent selection of the following points. apparatus: source, lead screen, ruler, γ ray and α particle detector such as a Geiger Muller tube, rate-meter or counter and stopwatch, named absorber of varying thicknesses may be used. safety: examples include, do not have source out of storage longer than necessary, use long tongs, use a lead screen between source and experimenter. measurements: with no source present switch on the counter for a fixed period measured by the stopwatch and record the number of counts or record the rate-meter reading with the source present measure and record the distance between the source and detector (or thickness of absorber) then switch on the counter for a fixed period measured by the stopwatch and record the number of counts or record the rate-meter reading repeat the readings for different distances (or thicknesses of absorber).		from results taken this is a harder mark to achieve it may involve establishing an inverse square fall in intensity in air or an exponential fall using thicknesses of lead if a continuous distribution is not used an absorber or distance in air that would just eliminate β (30-50cm air / 3-6mm Al) must be used with and without the source being present or compared to background

		use of measurements: for each count find the rate by dividing by the time if a rate-meter was not used subtract the background count-rate from each measured count-rate to obtain the corrected count-rate longer recording times may be used at longer distances (or thickness of absorber). plot a graph of (corrected) count-rate against distance (or thickness of absorber) or refer to tabulated values plot a graph of (corrected) count-rate against reciprocal of distance squared or equivalent linear graph to show inverse square relationship in air analysis: the presence of an α source is shown by a rapid fall in the (corrected) count-rate when the source detector distance is between 2 – 5 cm in air the presence of a γ source is shown if the <u>corrected</u> count-rate is still present when the source detector distance is greater than 30 cm in air (or at a range beyond that of beta particles in any other absorber, e.g. 3 mm in Al) the presence of a γ source is best shown by the graph of (corrected) count-rate against reciprocal of distance squared being a straight line through the origin		

Section B – Medical Physics

Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)		**<u>Only</u>** cones at fovea ✓ as you move away from fovea fewer cones more rods ✓	2	Allow centre for fovea
1	(b)		three labelled curves blue, green, red in order from left to right ✓ roughly at correct height ✓ Green > Red >> Blue each curve covers the correct range of wavelengths Blue 375 to 500; Green 425 to 675; Red 475 to 725 (all + or – 30} ✓	3	Green>red>2/3green Blue<1/4green
1	(c)		the two images fall on receptors with at least one (unstimulated) receptor between them ✓	1	Allow 'separated by at least 2 cell diameters'
1	(d)		Cones used in bright light, rods used in dim light resolution in bright light better because size of cones smaller than size of rod: or resolution in dim light worse because several rods connected to 1 nerve (well away from fovea)	2	Do not accept, 'greater density of cones'
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. **Good to Excellent** 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 explains the principles of transfer of vibrations, from mechanical vibration of the ear drum, through mechanical oscillations of*	Mark range 5-6	

			the malleus, incus and stapes acting as a lever system, producing mechanical vibration of the oval window and then pressure waves in the fluid in the cochlea. They use the correct names of the relevant parts of the ear *They then explain the increase in pressure with sensible use of numbers, reduction in area of about 20 and increase in force of about 1.5, resulting in pressure increase of about 30.*		
			Modest to Adequate 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 explains some of the principles of transfer of vibrations and mentions some of the names of the relevant parts of the ear. They talk about the increase in pressure, but may fail to add relevant numbers*	3-4	
			Poor to Limited 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 explains a principle of transfer of vibrations or explains the increase in pressure and mentions at least one of the names of the relevant parts of the ear*	2-1	
			Incorrect, Inappropriate or No Response No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	0	
			The explanation expected could include the following: Outer ear acts as a funnel gathering waves into the ear canal pressure waves incident on eardrum eardrum vibrates, mechanical vibrations mechanical vibrations passed through a system of three bones acting as		

			levers malleus, incus and stapes the last bone sets the oval window into mechanical vibration this produces pressure waves in the liquid in the cochlea. three bone lever system increase force by about 1.5 (1.3 to 1.7) times ✓ cross sectional area of the oval window about 20 (15 to 25) times less than the cross sectional area of the eardrum ✓ larger force / smaller area gives pressure about 30 times greater, (any answer for pressure, to agree with other values quoted)		
2	(b)		Intensity is the power per unit (cross-sectional) area (in path of the wave) ✓ At normal incidence ✓	2	
2	(c)		rearrange equation to give I= ✓ correct answer 2.5(12) x 10^{-7} W m^{-2} ✓ correct to 2 sig figs ✓	3	
3	(a)		Alternating potential difference applied across the crystal ✓ causes crystal to expand and contract ✓ creating pressure waves in the crystal / plastic membrane ✓ frequency of alternating pd equal to that of crystal /resonant frequency of crystal✓ which is above 20 kHz ✓ short application of ac to produce short pulse ✓ use of backing material to damp and stop vibration of crystal ✓	Max 4	
3	(b)	(i)	correct calculation of ratio I_r / I_i = 0.99896 ✓ subtract from 1 and multiply by 100 to give 0.10% ✓	2	Do not give mark for 99.8 ecf from calc for 2nd mark

3	(b)	(ii)	gel is between the probe and the skin to exclude air ✓ gel should have acoustic impedance equal/close to that of the skin/soft tissue ✓ to ensure maximum transmission/greatly increase transmission into the body: or to minimise reflection / greatly reduce reflection at body boundary ✓	Max 2	
4	(a)		both mV and ms labelled as units ✓ time scale 0 to 5 overall time for peak shape to be >0.75 ms and <4ms ✓ potential scale resting -70 to peak +30; (allow values between -90 and -70: +20 and +40) ✓	3	Allow any correct units, but then values on scales must match
4	(b)	(i)	-70mV ✓	1	Ecf from graph
4	(b)	(ii)	Depolarisation ✓ Na^+ ions <u>into</u> the membrane/cell/axon ✓	2	Need positive sodium ions
4	(b)	(iii)	Repolarisation ✓ K^+ ions out of the membrane/cell/axon ✓	2	Need positive potassium ions