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General Certificate of Education (A-level)
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Physics B: Physics in Context PHYB5

(Specification 2455)

Unit 5: Energy under the microscope

Final

Mark Scheme

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Question	Marking guidance		Mark	Comment
1 (a) (i)	α – 4,2 C – 12, 6 n – 1,0	B1 B1 B1	3	
1 (a) (ii)	several (fast) neutrons produced (in each fission) Nucleus must <u>absorb</u> neutron (to make U 236) (in order to fission)	B1 B1	2	Must have some indication that there is more than 1 neutron Must have a clear indication that neutron is absorbed – not just collides. Absorption must be by <u>nucleus</u>
1 (b) (i)	(measure of the) probability of a neutron being absorbed (when it impacts nucleus) – allow (target) area (of nucleus) in order to be absorbed	B1	1	eg the cross-sectional area of the nucleus that can absorb the neutron
1 (b) (ii)	barn / 10^{-28} m^2 / 10^{-24} cm^2	B1	1	Not m^2
1 (c) (i)	slow neutrons down slow neutrons have greater probability of causing fission or being absorbed by U-235 or a fissile isotope (wtte) / nucleus has larger cross section for slower neutron	B1 B1	2	
1 (c) (ii)	idea of neutron economy / preserve neutrons so that they can cause future fissions	B1	1	

1 (c) (iii)	light atoms slow neutrons more quickly / with fewer collision (so they are less likely to be lost to the system)	B1	1	Condone makes the moderator more effective – quite generous but do not allow T.O.

2 (a)	thermionic emission / by heating cathode heated / heating done by electric current / overcoming work function anode which is positive wrt cathode / accelerated by electric field between anode and cathode	B1 B1 B1	3	Must mention anode for third mark

2 (b) (i)	one relevant equation seen: $E = V/d$ / $F = Ee$ / $a=F/m$ $a = \dfrac{1.6 \times 10^{-19} \times 270}{9.1 \times 10^{-31} \times 0.015}$ / F = 2.88×10^{-15} 3.16×10^{15} (m s^{-2})	B1 B1 B1	3	Equation should be in symbols Substitution may be done in several stages Must be more than 2 sf

2 (b) (ii)	$s = (ut) + ½ at^2$ or $v = u + at$ and $s = v_{av}t$ OR $s = vt$ used 3.56×10^{-3}m	B1 B1	2	Appropriate symbol equation seen and used for 1st mark Expect at least 3 sf but condone 3.6 for candidates who use a = 3.2×10^{15}

2 (b) (iii)	$v = u + at$ / $v = at$ $v^2 = u^2 + 2as$ used 4.74×10^6 m s^{-1} to at least 3 sf	B1 B1	2	May also use $eV = ½mv^2$ Allow 4.8 (2 or more sf) – consistent with use of $a = 3.2 \times 10^{15}$

2 (b) (iv)	t = 7.5 x 10^{-9} s seen or used 3.53 x 10^{-2} (m) **ecf** for wrong t adds 3.56 x 10^{-3} (m) to their 3.53 x 10^{-2} clipped with b(i) and b(ii)	C1 A1 B1	3	May use ratios for 1st 2 marks: $s_v/s_h = v_v/v_h$ C1 3.53 x 10^{-2} (m) A1 Allow reasonable rounding
3 (a) (i)	mass destroyed (and energy produced) / Binding energy increased $E = \Delta mc^2$ energy in form of KE (of the products) idea that internal energy increases when KE of particles increases MAX 3	B1 B1 B1	3	
3 (a)(ii)	converts 17.59 MeV to J (2.8 x 10^{-12}) seen uses $E = \Delta mc^2$ mass defect calculated (3.127 x 10^{-29} seen) Divides by 1.66 x 10^{-27} to convert their mass defect to amu / 0.0188(38) 3.0166	C1 C1 C1 C1 A1	5	Allow reasonable rounding at each stage - should be correct to 4sf for final answer
3 (b)(i)	mixture of positive ions and electrons (+ complete atoms) / (partly) ionised gas ionisation happens due to very high temp	B1 B1	2	

3 (b) (ii)	energy = 1.5kT stated 7.7×10^{-14} (J) / 7.66×10^{-14} (J)	B1 B1	2	Must see equation with appropriate subject but condone ½ mc^2 At least 2 sf

3 (b)(iii)	$PE = Qq/4\pi\varepsilon_o r$ used $3.1 \times 10^{-13} = \frac{(1.6 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times r}$ 2.9×10^{-15} or 1.5×10^{-15} or 7.5×10^{-16} (m) 7.5×10^{-16} or 1.5×10^{-15} (m)	C1 C1 C1 A1	4	equation with subject – use means substitution or rearrangement Condone 1.53×10^{-13} or 7.66×10^{-14} 8×10^{-14} or 1.6×10^{-13}

3 (c)	The marking scheme for this question includes an overall assessment for the quality of written communication (QWC). There are no discrete marks for the assessment of QWC but the candidate's QWC in this answer will be one of the criteria used to assign a level and award the marks for this question. **Descriptor** – an answer will be expected to meet most of the criteria in the level descriptor. **Level 3 – good** -claims supported by an appropriate range of evidence -good use of information or ideas about physics, going beyond those given in the question -argument well-structured with minimal repetition or irrelevant points -accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling			

3 (c)	**Level 2 – modest** -claims partly supported by evidence, -good use of information or ideas about physics given in the question but limited beyond this the argument shows some attempt at structure -the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling **Level 1 – limited** -valid points but not clearly linked to an argument structure -limited use of information about physics -unstructured -errors in spelling, punctuation and grammar or lack of fluency **Level 0** -incorrect, inappropriate or no response examples of the sort of information or ideas that might be used to support an argument: Points to look for: <u>How contained</u> toroid not to touch sides temp too high or destroy plasma control by mag fields		6	5 – 6 Significant coverage of both topics 3 – 4 Both topics mentioned with detail for at least one. One topic exhaustively covered could access 3 marks 1 – 2 Aspects of 1 topic

	<u>Magnetic field</u> superconductivity defined need for very powerful electro magnets energy loss = I^2R heating in magnets would melt magnets without superconductivity			
4 (a) (i)	Induction/intake, compression, power/ignition/combustion, exhaust in this order	B1	1	
4 (a) (ii)	Being compressed by piston (moving up) / adiabatic compression	B1	1	More than just compression
4 (a) (iii)	(Kinetic energy) of flywheel or crankshaft / power stroke in other cylinders	B1	1	
4 (a) (iv)	(exhaust / burned) gases leaving cylinder	B1	1	
4 (a) (v)	work done expelling exhaust and/or drawing in new air	B1	1	
4 (b)	Attempt to find area 16 to 19 squares / each square 25 (J) 400 to 475 (J)	C1 C1 A1	3	Condone addition or subtraction of triangle EAB (about 1.6 squares)

4 (c) (i)	$Q=ms\Delta T$ used (numbers or symbols) $Q=mL$ *used* (numbers or symbols) any single value correct (1680, 8750, 11300) 21 730 (J) / 2.17 x 10^4 **cao**	C1 C1 C1 A1	4	For this question, allow sight of the appropriate numbers multiplied together without a proper equation for the first 2 marks
4 (c) (ii)	efficiency = $\frac{T_H - T_c}{T_H}$ uses absolute temps (723 and 423) 0.41(5) or 41(.5) or 42%	C1 C1 A1	3	Can be symbols or ^oC or K
4 (c) (iii)	(some of) energy in steam does (useful) work (pushing cylinder down idea that less energy lost in exhaust gases / less energy wasted	B1 B1	2	
4 (c) (iv)	1st law equation stated $\Delta U = Q + W$ (or in words) work done by steam / W is negative Q or heating done to gas/water/steam = 0 / no heating internal energy of gas decreases (as expansion is adiabatic)	B1 M1 M1 A1	4	
5 (a)	Idea that energy is used to create (massive) particles Creation of more massive particles requires more energy	C1 A1	2	Quoting $E = \Delta mc^2$ may support this argument

5 (b) (i)	Cause particles to move in circle as particle speed or mass increases (relativistically), B field or force must increase (to maintain same diameter) reference to $Bqv = mv^2/r$ or $B = mv/qr$	B1 B1 B1	3	

5 (b) (ii)	Fields are to increase speed / velocity / ke of particles Frequency increases tube length is constant / time between accelerations reduces (as particle speed increases) / time spent in tube reduces Max 2	B1 B1	2	Not just accelerate

5 (c)	uses $m=m_o/\sqrt{(1-v^2/c^2)}$ mass = 6.5×10^{-27} uses $E_k = ½ mv^2$ 2.7×10^{-10} (J) / divides by 1.6×10^{-10} or 1.6×10^{-19} 1.7(1) (GeV)	C1 C1 C1 C1 A1	5	

5 (d) (i)	Can produces particles of higher energy / faster than synch produce continuous streams of particles No needs for magnets in a LINAC electrons in synchrotrons lose energy by synchrotron radiation Max 2	B1 B1	2	

5 (d) (ii)	proton beam therapy producing isotopes pre-accelerating particles for other accelerators non-specific reference to medical physics gets one	B1 B1	2	Condone neutron production

6 (a) (i)	relative atomic mass/Atomic mass / nucleon number/ is 99 OR it has 99 nucleons / protons & neutrons in the nucleus metastable exists in this state for a long time (cf other gamma emitters)	B1 B1 B1	3	

6 (a) (ii)	short half life – patient not exposed for long / causes little damage to patients half life sufficiently long for measurements to be made gamma has low energy / not very ionising (and is not very damaging) radiation be detectable outside body gamma emitter – gamma will penetrate skin daughter nucleus produces only low energy beta daughter has long half life / low activity ANY 4	B1 B1 B1 B1	4	

6 (b) (i)	uses dN/dt = λN multiplies by 99 AND divides by 6 x 10^{23} 7.3(4) x 10^{-6}g or 7.3(4) x 10^{-9} kg	C1 C1 A1	3	

6 (b) (ii)	Use of correct formula: $A = A_o e^{-\lambda t}$ eg $0.17 = 1.3e^{-\lambda t}$ takes logs correctly – look for $\ln\left(\frac{1.7\ x\ 10^{10}}{1.3\ x\ 10^{11}}\right) = -2.92\ x10^{-6}t$ 6.9(7) x 10^5s / 194 h / 8.1 d	C1 C1 A1	3	Ignore power of ten – condone wrong λ or half life or reversal of A and A_o (1.7 and 1.3) Allow correct taking of logs even for an incorrect equation Allow sensible rounding Unit must be consistent

6 (c)	two values found and averaged half thickness 1.75 to 1.85 (cm) use of $\mu = .693/x$ or Selects 1 points on the graph and substitutes into $I = I_o e^{-\mu x}$ 0.37 to 0.39 cm^{-1}	B1 C1 C1 A1	4	May work backwards from absorption coefficient calculated by alternative method For candidates using this variation, to achieve the first B mark, they will need to do the substitution twice for different points Beware of incorrect units