A-LEVEL

PHYSICS B: PHYSICS IN CONTEXT

PHYB5 – Energy Under the Microscope
Mark scheme

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COMPONENT NAME: Unit 5 – Energy Under the Microscope

COMPONENT NUMBER: PHYB5

Question	Part	Sub Part	Marking Guidance	Mark type	Mark	Comments
1	(a)	(i)	Exhaust – waste gases are released into the surroundings (as the piston moves upwards) Induction –air/fuel is sucked/introduced/drawn into the cylinder (as the piston moves down)	M1 A1	2	OWTTE
1	(a)	(ii)	When compressing air work is done **on** the air/ energy transferred to the air/internal energy increased/KE of molecules increases temperature rise sufficient/enough to ignite the fuel	M1 A1	2	
1	(b)		Use of *pV/T* = constant e.g. $\frac{49\times1.5}{1940} = \frac{3.02\times10.9}{T}$ 869 (870) K OR Calculation of *n* or the 'constant' Substitution using their *n* or their constant 869 (870) K	C1 C1 A1 C1 C1 A1	3	or calculates *n* and then *T* May use data for A B or C Condone powers of 10 **or** Use of constant volume change data Gives 867

1	(c)	(i)	Use of $pV=nRT$ Allow $n = pV/RT$ or substitution condoning incorrect powers of 10 $1.01\times10^{5} \times10.9\times10^{-4} = n\times8.3\times290$ (e.g.) 0.045 - 0.046 Penalise 1 sf OR Calculate N using $pV = NkT$ $n = N/N_A$ Answer as above	C1 C1 A1 C1 C1 A1	3	Using data for A B C or D Including correct powers of 10

1	(c)	(ii)	Calculation of N $0.046 \times 6.0 \times 10^{23}$ $1.01\times10^{5} \times 10.9\times10^{-4} = \frac{1}{3} 2.8\times10^{22} \times4.8\times 10^{-26} <c^{2}>$ $2.45(2.5) \times 10^{5}$ allow 2.6×10^{5} from rounding N to 2 sf $m^{2}\ s^{-2}$ cao OR $3/2\ kT = 1/2\ m<c^{2}>$ $3 \times 1.38 \times 10^{-23} \times 290 = 4.8\times 10^{-26} <c^{2}>$ 2.5×10^{5} $m^{2}\ s^{-2}$ cao	C1 C1 A1 B1 C1 C1 A1 B1	4	Condone calculation of rms speed of 496 (500)

1	(d)		Attempt to use pV (calculates pV for B or C) **Using graph** Or ΔV = 1.5 – 0.68 or 0.82 seen 1.5 – 0.7 $(49\times10^{5}$ x $0.82\times10^{-4})$ 400 (402 401.8) J 390 J		3	condone power of 10 error minus sign loses last mark
1	(e)		ΔU negative Q negative W zero	B1 B1	2	
2	(a)		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 **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	B1 x6	6	

			Level 0 -incorrect, inappropriate or no response			
			Answer could include: Suitable diagram showing structure suitably labelled Ions enter the selector at different speeds Use of crossed electric and magnetic fields. Selector designed so that forces produced by the fields are opposite Magnetic force on an ion is Bqv Magnetic force perpendicular to both B and v Electric field produced by potential difference between two plates $E=V/d$ Electric force on an ion is Eq Force in direction of E for positive ions For one velocity forces cancel so no deflection (and pass through collimator/exit hole) $F = Bqv = Eq$ This happens when $v = E/B$ Velocity selected is Independent of charge on the ion **Level 3** This will be a coherent response which will include all the important points. Equations will be explained. Force directions will be explained and terms in the equations defined. They will be clear that initially there are a variety of speeds and the and the condition for the selected velocity stated. They may go on to explain what happens to the unselected ions. There may be a good helpful diagram. **Level 2** This may lack coherence and/or a largely qualitative response with some attempt to use equations. The condition for the velocity selected should be stated. Terms may not be adequately defined and some aspects are only inferred rather than stated. The diagram may be incomplete and lack labelling. **Level 1** This may be a response that will be superficial answer to the question and be largely descriptive with little attempt to provide explanations. Communication may be of a poor standard. **Level 0** This will contain no relevant physics			Ignore reference to other parts of the system

2	(b)	(i)	Arrow toward centre of circle	B1	1	

2	(b)	(ii)	Ions would lose energy in collisions/slow down/reduce velocity Path would not be circular Collisions may cause/dispersion/scattering/deflection/change in direction of ions **ANY 2**	B1 B1	2	Not just 'collide with...'or ionisation

2	(b)	(iii)	40/50 or 0.8 seen (allow 40/)(50±2) 80% cao	C1 A1	2	

2	(b)	(iv)	$Bqv = \frac{mv^2}{r}$ leading to $m = \frac{Bqr}{v}$ substitution before or after changing subject $m = \frac{B \times 3.2 \times 10^{-19} \times 0.055}{15000}$ *m* =1.17×10^{-24} *B*	B1 B1 B1	3	 not $1.6 \times 10^{-19} \times 0.11$ 3 sf required

2	(b)	(v)	*B* = 0.0348 ±0.0001 or 0.348 ±0.001 (4.16 to 4,18) $\times 10^{-26}$ kg (if 1.2 used) 4.07 (if 1.17 used)	M1 A1	2	 value depends on rounding off

2	(b)	(vi)	Charge on ion = +2 so atom has lost 2 electrons Electrons = 10 Number of nucleons =$(4.01\times10^{-26})/(1.67\times10^{-27})$ = 24 Neutrons=12	B1 B1 M1 A1	4	Or calculates mass of protons, subtracts from given mass and divides by mass of neutron.or similar approach.

3	(a)	(i)	Use of Q = *CV* 0.18 C	C1 A1	2	Allow substitution ignoring µ

3	(a)	(ii)	Use of $V = V_0 e^{-t/RC}$ substitution with incorrect power of 10 for *C* and *t* e.g. $650=1800\ e^{-0.0075/(0.0001R)}$ 74 to 77 Ω OR time to halve = 5.2 ± 0.1 m s sub in $T_{1/2} = 0.69 \times 100 \times 10^{-6} R$ 72 to 80 Ω	B1 B1 B1 B1 B1 B1	3	**or** ln(650/1800) = –0.0075/(0.0001*R*) condone incorrect power of 10 but $T_{1/2}$ must be in range 5.0 to 5.5 ms

3	(b)	(i)	Energy = ½ CV^2 used or ½ QV with Q = 0.18 and V = 1800 Or one energy correct (162 and approx. 20 to 25) ½ (100 x 10^{-6}) (1800^2 – 680^2) Approx. 137 to 142(J) depending on read off for final V OR Mean current = (0.18-0.07)/7.5 x 10^{-3} =14.7 A Mean V = 1250 ±50 V E = (mean V) x 14,7 x 7,5 x 10^{-3} = 137 (J)	B1 B1 B1	3	 (allow 660 to 700V)

3	(b)	(ii)	150 –(their (b)(i) if 8 J to 13 J 10 J using given 140 J	B1	1	

3	(b)	(iii)	4.8±0.1 x 10^{-3} (s) substitution in Energy = $I^2 Rt$ their (b)(ii) = I^2 x 75 x 4.8 (x10^{-3}) 4.6 (A) to 6.1 (A) ecf Using data supplied E = 10 so I = 5.3 (A) Allow 1 sf OR 4.8 x 10^{-3} (s) calculates change in charge 60 mC - 32mC = 28mC (allow 28 to 30 mC) current = 5.7 to 6.4 A	C1 C1 A1	3	 Condone no (10^{-3}) Allow 2 for Average pd estimate about 450V Current = 450/75 = 6 A

3	(c)		Rate of discharge is quicker/discharge current higher (If discharge times and initial voltage are the same then) capacitors deliver too much/more energy Need a lower initial *V* for both C_1 and C_2 **or** Need to reduce discharge times for both C_1 and C_2	B1 B1 B1	3	Not increase C values
4	(a)		Alpha /or beta decay leaves <u>nucleus</u> in an excited state Energy lost to return <u>nucleus</u> to the ground/unexcited state Energy change in <u>nucleus</u> is the energy of the gamma ray photon ANY 2 PLUS Frequency of the gamma radiation = *E/h* /is given by *E =hf*	B1 B1 B1	3	Nucleus must be mentioned in one of the statements
4	(b)		(Used internally) as tracers allowing external monitoring/use in PET scanner (Used externally) to irradiate and kill cancer cells/cancer treatment (allow radio therapy)	B1 B1	2	Not gamma form e^+/e^- annihilation

4	(c)	(i)	Radiation through window = 880 x 100/1.5 min^{-1} or counts per sec = 880/60 (14.7s^{-1}) (58700 min^{-1} or 978 s^{-1}) Total area of sphere at 0.25 m = 4 πr^2 (0.785 m^2) or 4 π $(0.25)^2$ Ratio of areas seen 4 πr^2/(1.4 x 10^{-4}) = (5607) (Condone attempt using incorrect sphere area) 5.5 (5.48) × 10^6 becquerel (Bq)	C1 C1 C1 A1 B1	5	3..29 x 10^8 allow 3 for the calculation(forgets to ÷60) Allow differences due to sensible early rounding off Must be capital B if abbreviation used Condone capital if written in full and allow reasonable spelling

4	(c)	(ii)	Attempt to use $I=I_o e^{-\mu x}$ allow gives ln form $\ln(I/I_o) = -\mu x$ $115=880e^{-\mu 3.5}$ or $1.9 = 14.7\ e^{-\mu 3.5}$ or $115=880e^{-\mu 0.0355}$ 0.58 or 58 cm^{-1} or m^{-1}	C1 C1 A1 A1	4	Allow I and I_o wrong way round for 'use of' Allow unit that is consistent with unit for μ in the working

4	(c)	(iii)	Two sensible precautions: Only remove box from storage when needed Handle source with tongs/don't handle with hands Erect lead shielding between source and observation point Keep monitoring position as far from the source as possible Condone not pointing at anyone **ANY 2**	 B1 B1 B1 B1	2	Not use gloves Too weak given that question says 'when setting up… Washing hands/no eating, drinking

5	(a)	(i)	B: 92 and 234	B1	1	Auto marked

5	(a)	(ii)	Low penetration/ more easily absorbed **All** energy converted to thermal energy in short distance Lower risk to personnel and equipment outside the RTG (OWTTE) Less shielding needed (so less mass in spacecraft)	B1 B1	2 max	Not carry more energy/more easily absorbed

5	(b)		Decay constant = 0.69/(88 ×3.15 × 10^7) =2.49 × 10^{-10} s^{-1} Attempt to use $A = \lambda N$ (9.44 × 10^{15} if correct) Power available from source= A × 8.8 × 10^{-13} W = 8300W Efficiency = 380/8300 = 4.6%	C1 C1 C1 A1	4	May use incorrect decay constant Each step may be in numerical equation form

5	(c)		Use of $N=N_o e^{-\lambda t}$ Decay constant = 0.69/88 =7.8 x 10^{-3} (y^{-1}) or uses decay constant from 5bi and converts 12 years to s (3.78 x 10^8) N = 3.79 x $10^{25}e^{-0.00784x12}$ Number left 3.45(3.5) x 10^{25} Atoms that decay = (3.79 –(their number left) x 10^{25} 3.4 x 10^{24} if correct	C1 C1 C1 A1 B1	5	Can work in years or convert Condone power of 10 errors Condone 2.9 x 10^{24} by early rounding Allow max 3 for answer assuming activity constant for 12 y (3.6 x 10^{24})

5	(d)		Temperature increases Energy produced depends on volume and energy lost on surface area Or Energy produced increases by a factor of 8 OR energy lost increases by a factor of 4 Energy lost depends on $4\pi r^2$; energy produced depends on $4/3\ \pi r^3$ **or** Doubling radius increases energy loss by factor of 4 and energy gain by factor of 8	B1 C1 A1	3	Allow answer in terms of proportionalities
6	(a)		Mass of deuteron in J = $1875.6\text{x}10^{6}$ x 1.60×10^{-19} = $3.00(1) \times 10^{-10}$ Mass in kg = $3.001 \times 10^{-10}/(3\text{x}10^{8})^2 = 3.333(3.334)\text{x}10^{-27}$kg Total mass of a proton + neutron = $3.348\ \text{x}10^{-27}$ kg Mass defect = 1.3 to 1.5×10^{-29} kg Using 2 sf values gives 3.35×10^{-27} kg Mass defect = $1.7\ \times 10^{-29}$ kg Allow 3 marks Arriving at 0.6×10^{-29} kg Allow 3 marks (due to incorrect rounding off of neutron mass)	C1 C1 C1 A1	4	Use of 1.661×10^{-27} loses this mark =gives 3.222 x … Negative mass defect Using mixed units so 2 only
6	(b)	(i)	Momentum $p = mv$ or $v = p/m$ Substitution and manipulation to give ½ mv^2 or substitute for v in ½ mv^2 etc	B1 B1	2	

6	(b)	(ii)	Momentum of alpha = $\sqrt{}(2 \times 6.68 \times 10^{-27} \times 3.56 \times 10^{6} \times (1.6 \times 10^{-19}))= 8.72 \times 10^{-20}$ N s $\sqrt{}(2 \times 4 \times 3.56 = 5.4$ Momentum of neutron $\sqrt{}(2 \times 1.68 \times 10^{-27} \times 14.03 \times 10^{6} \times (1.6 \times 10^{-19}))=8.68 \times 10^{-20}$ $\sqrt{}(2 \times 1 \times 14.03 = 5.3$ Appreciation that the momentum changes of the particles are equal and opposite so still 0 momentum.	B1 B1 B1	3	Condone no conversion to J or eV **or** using mass of alpha = 4 mass of neutron Must be stated
6	(c)		(Induced fission requires the) absorption/addition of a neutron by/to <u>a nucleus</u> (Unstable) nucleus splits into two (lighter) nuclei (and further neutrons)	B1 B1	2	Not atom/isotope
6	(d)	(i)	More plentiful supply of raw materials Dealing with waste products less problematic/less harmful waste/products not radioactive Obtain more energy per unit mass/per kg **ANY TWO**	B1 B1	2	Not NO radioactive waste
6	(d)	(ii)	Problems : Control of plasma Extracting the energy produced High temperature needed/hard to achieve Addition of fuel to sustain reaction **ANY TWO**	B1 B1	2	