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General Certificate of Education
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Physics B: Physics in Context PHYB5

Energy Under the Microscope

Unit 5

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 meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting 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 the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting 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.

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NOTES

Letters are used to distinguish between different types of marks in the scheme.

M indicates OBLIGATORY METHOD MARK
This is usually awarded for the physical principles involved, or for a particular point in the argument or definition. It is followed by one or more accuracy marks which cannot be scored unless the M mark has already been scored.

C indicates COMPENSATION METHOD MARK
This is awarded for the correct method or physical principle. In this case the method can be seen or implied by a correct answer or other correct subsequent steps. In this way an answer might score full marks even if some working has been omitted.

A indicates ACCURACY MARK
These marks are awarded for correct calculation or further detail. They follow an M mark or a C mark.

B indicates INDEPENDENT MARK
This is a mark which is independent of M and C marks.

ecf is used to indicate that marks can be awarded if an error has been carried forward (ecf must be written on the script). This is also referred to as a ‘transferred error' or 'consequential marking'.

Where a correct answer only (**cao**) is required, this means that the answer must be as in the Marking Scheme, including significant figures and units.

cnao is used to indicate that the answer must be numerically correct but the unit is only penalised if it is the first error or omission in the section (see below).

Marks should be awarded for **correct** alternative approaches to numerical question that are not covered by the marking scheme. A correct answer from working that contains a physics error (PE) should not be given credit. Examiners should contact the Team Leader or Principal Examiner for confirmation of the validity of the method, if in doubt.

GCE Physics, Specification B: Physics in Context, PHYB5, Energy under the Microscope

Question 1			
(a)	energy/heat needed to raise the temperature	**M1**	**2**
	energy/heat needed to raise the temperature of 1 kg of a substance by 1K/°C	**A1**	
(b) (i)	energy removed per second = 56 kJ	**B1**	**4**
	energy = *mc* × rise of temperature $E = mc\Delta\theta$ (or ΔT) **or** 56000 = 2.5 × *c* × 7 allow any recognisable energy substitution (eg 280 000)	**C1**	
	3200 (3214) or 16000 or 12800	**A1**	
	$\text{J kg}^{-1}\text{K}^{-1}$	**B1**	
(b) (ii)	energy input calculated = 373(.3) (kJ) **or** $0.25 = \frac{Q_{in} - Q_{out}}{Q_{in}}$ or useful energy = 1/3 of 280	**C1**	**2**
	93(.3) (kJ)	**A1**	
(b) (iii)	efficiency = $(T_H - T_C)/T_H$ (× 100%)	**B1**	**3**
	can only be 100% efficient if heat sink is at 0 K	**B1**	
	this is impracticable/impossible normal sink temperature is about 300 K	**B1**	
	or this would need the entropy change to be zero	**B1**	
	(in spontaneous changes) entropy increases	**M1**	
	so impossible	**A1**	
		Total	**11**

Question 2			
(a) (i)	proton number 0	**B1**	**3**
	nucleon number 1	**B1**	
	neutron	**B1**	
(a) (ii)	positive/similar charge on oxygen nucleus and proton	**B1**	**max 2**
	energy needed to do work against the repulsive force/to overcome the repulsive force	**B1**	
	must get close enough for strong force to be effective	**B1**	

(a)	(iii)	use of $A = A_0 e^{-\lambda t}$ with 20 as A **or** λ=0.00627 (min^{-1}) **or** 1.045 × 10^4 (s^{-1}) or 0.38 h^{-1} with appropriate working	C1	3
		$20 = A_o e^{-0.00627 \times 180}$ or $20 = A_o e^{-0.0001045 \times 108000}$ r $20 = A_o e^{-0.38 \times 3}$	C1	
		62.2 -62.5(62) GBq	A1	
(a)	(iv)	use of $A = \lambda N$ or $A = 20 \times 10^9$ seen	C1	2
		1.91×10^{14}	A1	
(b)	(i)	force = mv^2/r and $F = Bqv$ seen	B1	3
		$v = Bqr/m$	B1	
		energy = ½mv^2 leading to = ½m $(Bqr/m)^2$	B1	
(b)	(ii)	identifies mass and charge of proton correctly **in substitution**	C1	3
		0.62 – 0.63	C1	
		T or Wb m^{-2} or N A^{-1} m^{-1}	A1	
			Total	**16**

Question 3				
(a)	(i)	appropriate test applied correctly once eg ratio found for two coordinates with specified Δx	M1	3
		appropriate test applied correctly once ratio found for different pair of coordinates for same Δx	M1	
		conclusion statement or clear evidence of how test demonstrates exponential change	A1	
(a)	(ii)	thickness of absorber required	B1	2
		count rate/Intensity reduced to half the original value to absorb half the radiation (incident on the absorber)	B1	
(a)	(iii)	photon energy	B1	2
		density/absorber material	B1	
(a)	(iv)	$0.5 = e^{-\mu \text{ (their half thickness)}}$	C1	3
		0.0866 (0.087) or 86.6 (87)	A1	
		mm^{-1} or m^{-1} or cm^{-1}	B1	

(b)	max **four** from lower exposure means lower risk to user knowledge of half thickness **allows calculation of** absorber of suitable thickness to reduce intensity using (same material) 2 × half thickness ⇒ ¼ intensity **or** using (same thickness of) a material with double half thickness ⇒ ½ intensity intensity reduced by increasing distance from the source intensity reduced ¼ by doubling distance form source	 **B1** **C1** **A1** **C1** **A1**	**max 4**
		Total	**14**

Question 4			
(a)	**advantage** less energy loss by synchrotron radiation no need for magnets to control beam continuous beam **disadvantage** (very) long more accelerating sections	**B1** **B1**	**2**
(b) (i)	$eV = ½ mv^2$ $4.8\ (\times 10^3) \times 1.6 \times 10^{-19} = ½\ 9.1 \times 10^{-31}\ v^2$ 4.108 (4.106 if 9.11 used) $\times 10^7$ (m s^{-1}) cnao	**B1** **B1** **B1**	**3**
(b) (ii)	0.072 or 0.074 (m) (72 or 74 mm)	**B1**	**1**
(b) (iii)	$m = \dfrac{9.11 \times 10^{-31}}{\sqrt{\left(1 - \left(\frac{4 \times 10^7}{3 \times 10^8}\right)^2\right)}}$ 9.192×10^{-31} (kg) **or** 0.0009009 m_o seen $8.2(1) \times 10^{-33}$ (kg)	**C1** **C1** **A1**	**3**
(b) (iv)	(some energy goes to) increase in mass so lower velocity (energy supplied) increases mass rather than velocity length required decreases	**M1** **A1**	**2**
		Total	**11**

Question 5				
(a)	(i)	a nucleus splits (into less massive particles) **or** decays into particles with less total mass (owtte)/more BE **or** emits radiation (to become more stable)	**B1**	**2**
		without any outside influence/external factors	**B1**	
(a)	(ii)	correct calculation of mass change 0.0061194 (u) or 1.01643 × 10^{-29} (kg) seen	**B1**	**3**
		use of $\Delta E = \Delta m c^2$ with identifiable mass	**C1**	
		9.15 × 10^{-13} (J) cnao	**A1**	
(a)	(iii)	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 answer supported by an appropriate range of evidence good use of information or ideas about physics, going beyond any given in the question answer well structured with minimal repetition or irrelevant points accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling		**5-6**
		Level 2 – modest answer partially supported by evidence good use of information or ideas about any physics given in the question but limited beyond this the answer shows some attempt at structure the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling		**3-4**
		Level 1 – limited valid points but not clearly linked to an argument structure limited use of information or ideas about physics unstructured errors in spelling, punctuation and grammar or lack of fluency		**1-2**
		Level 0 incorrect, inappropriate or no response		**0**

		possible points • use of a thermocouple • energy from alpha particle used to heat metal in contact with one junction • temperature difference between the two junctions • there are many junctions forming a thermopile • produces an emf **in a pacemaker** • radiation causes ionisation • possibility of damage to cells • could cause cancer • source may be damaged causing leak of r/a material • risk could outweigh benefit		
(b)	(i)	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$	C1	4
		charge on alpha particle 3.2×10^{-19} **or** $(90 \times 1.6 \times 10^{-19})$ **or** 2 and 90 seen	C1	
		$F = \frac{3.2 \times 10^{-19} \times 90 \times 10^{-19}}{4\pi\varepsilon_0 (5.1 \times 10^{-14})^2}$	C1	
		15.9 (N) cnao	A1	
(b)	(ii)	attempt to use $F = ma$	C1	3
		mass of alpha = $4 \times 1.67 \times 10^{-27} = 6.68 \times 10^{-27}$ kg **or** $4.00150627 \times 1.661 \times 10^{-27}$ kg $= 6.65 \times 10^{-27}$ kg	C1	
		2.4×10^{27} (m s^{-2} their (b)(i)/(6.7×10^{-27}))	A1	
(c)	(i)	uranium **nucleus** absorbs/captures a neutron	B1	3
		uranium (236) nucleus (is unstable) splits into smaller/two nuclei	B1	
		neutron**s** released {2 or 3 (average of 2.4)}	B1	
(c)	(ii)	number of moles = 2.12 (0.5/0.235 or 500/235 seen)	C1	3
		their moles × Avogadro constant number of atoms = 1.28×10^{24} if correct	C1	
		their number of atoms/nuclei × 2.7×10^{-11}	C1	
		$3.4 – 3.5 \times 10^{13}$ (J)	A1	
			Total	**24**

Question 6			
(a) (i)	tangent drawn at $t = 0$	M1	2
	coordinates correct and manipulated correctly 0.015 to 0.020 (A) 15 mA – 20 mA **or** $V = 4000$ V as in (ii) then $I = 18$ mA	A1	
(a) (ii)	$V = 220 \times$ their (i) condoning powers of 10	C1	2
	about 4000 V (3300 – 4400 V)	A1	
	or use of $V = Q/C$; $V = 100$ mC/25 µF	C1	
	4000 V	A1	
(a) (iii)	more charge leads to increased potential difference across the capacitor	M1	3
	pd = $V_R + V_C$ **or** if V_C increases then V_R decreases	M1	
	(if V_R falls) so I falls	A1	
(b) (i)	use of energy = ½ Q^2/C or use of $C = Q/V$ and ½ QV	C1	2
	0.083(7) or 0.084 C condone 0.083 C	A1	
(b) (ii)	power = 14 kW	B1	1
(c)	time constant =5.5 s	M1	3
	sensible attempt to find the charge after 8.3 s – by calculation or reading from graph	M1	
	about 78 mC and needs to be 85 mC/has not reached 85 mC so designer's suggestion is not valid	A1	
		Total	13

Question 7				
(a)	(i)	moderator	**B1**	**1**
(a)	(ii)	10000 (eV)	**B1**	**1**
(a)	(iii)	neutron stops proton moves with velocity/momentum/energy of the neutron	**B1** **B1**	**2**
(b)		energy = 0.025 × 1.6 × 10^{-19} J or from ½ mv^2 use of E =3/2 kT 190 or 196 (K)	**B1** **C1** **A1**	**3**
(c)	(i)	max **three** from relates to colliding particles **or** neutron and a target/nucleus/uranium probability of interaction/absorption/collision the (effective) area of a target/for interaction/absorption/ collision to occur useful diagram drawn showing collision cross section states that to collide/be absorbed/interact the separation/ distance (apart) is $2r$ or d or $(r$ + R) **or** states that the collision cross section is π (r + R)^2 condone πd^2 refers to the absorption cross section of a **nucleus** being dependent on the energy/speed of a colliding particle (eg neutron)	 **B1** **B1** **B1** **B1** **B1** **B1**	**max 3**
(c)	(ii)	barn	**B1**	**1**
			Total	**11**