Version 1.0

General Certificate of Education (A-level)
January 2011

Physics B: Physics in Context PHYB5

(Specification 2455)

Unit 5: Energy under the microscope

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.

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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)	ratio of charge to potential	**C1**	**2**
	4.2 μC per volt etc	**A1**	
(b) (i)	method: time for voltage to half/tangent at origin/use of decay equation/1/e value	**B1**	**4**
	appropriate reading from graph ($T_{½}$ = 440 or 450 μs)	**B1**	
	substitution into correct equation	**B1**	
	R correct for method (151/152/155 Ω)	**B1**	
(b) (ii)	**B** smaller than **A**	**M0**	**2**
	B discharges faster/**A** discharges slower	**B1**	
	reference to decay equation/calculation for **B**	**B1**	
(c)	$E = ½ CV^2$ or ½ *QV* seen	**C1**	**3**
	both 4.0 (V) and 0.9 (V)/16.8 (μC) and 3.8 (μC) seen	**C1**	
	31.9 (μJ)	**A1**	
		Total	**11**

Question 2			
(a)	measure of disorder/number of ways in which an arrangement can exist/*Q* ÷ *T* with *Q* and *T* defined	**B1**	**1**
(b)	**any two from**		**max 2**
	contravenes arrow of time idea	**B1**	
	idea of degradation of energy	**B1**	
	any mention of the second law of thermodynamics	**B1**	
	physical impossibility of system totally converting heat to work	**B1**	
(c) (i)	$Q = mc\Delta\theta$ clearly used	**B1**	**4**
	use of $m_1c_1 (\theta_1 - \theta_f) = m_2c_2 (\theta_f - \theta_2)$ **or** $2.5 \times 127(50 - \theta_f) = 25 \times 4180 (\theta_f - 15)$	**B1**	
	15.1(1)°C	**B1**	
	subtraction of 15.0 to show $\Delta\theta < 0.2$ K	**B1**	
(c) (ii)	mean value of temperature (32.6°C)	**C1**	**5**
	conversion of candidate's temperature to K (305.7)	**C1**	
	correct heat transfer (1.1×10^4 J)	**C1**	
	ΔS = 36	**A1**	
	$J K^{-1}$	**B1**	

(c)	(iii)	use of heat transfer as in (c)(ii) and 288 K 38(.5)	B1 B1	2
(c)	(iv)	lead cools therefore entropy decreases giving negative entropy change water warms therefore entropy increases giving a positive entropy change	B1 B1	2
			Total	**16**

Question 3				
(a)	(i)	all quantities correct all units correct	B1 B1	2
(a)	(ii)	any four key points eg ● a gas consists of large number of molecules (that statistical rules can be use with certainty) ● each molecule has negligible volume when compared with the volume of the gas as a whole ● molecules are in constant rapid motion ● at any instant as many molecules are moving in one direction as in any other ● the molecules undergo perfectly elastic collisions with the walls of their containing vessel thus reversing momentum ● there are no intermolecular forces between the molecules in between collisions (energy is entirely kinetic) ● the duration of a collision is negligible compared with the time between collisions ● each molecule produces a force on the wall of the container ● the huge number of molecules (in even a small quantity of gas) will average out to produce a uniform pressure throughout the gas	B4	4
(b)	(i)	(**AB**) air compressed (by the piston) work done on the air **or** temperature/internal energy rises	B1 B1	2
(b)	(ii)	(**BC**) expansion (of mixture at constant pressure) heat supplied to the mixture by the combustion of fuel **or** WD on piston by gas or temperature/internal energy increases	B1 B1	2
(b)	(iii)	(**CD**) (mixture) expansion work done on the piston (producing torque) **or** temperature/internal energy falls	B1 B1	2
(b)	(iv)	(**DA**) pressure falls (at constant volume) temperature/internal energy falls **and** heat being removed **or** no work being done	B1 B1	2

(c)	(i)	1.513 (MJ)	**B1**	**1**
(c)	(ii)	0.591 (ecf from (c) (i)) three significant figures with some working	**B1** **B1**	**2**
(c)	(iii)	evidence of dividing by 45.3 ratios leading to 40 × 10^{-3} (0.0397) kg	**C1** **A1**	**2**
			Total	**19**

Question 4			
(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 or ideas with only minor errors of grammar, punctuation and spelling		**5-6**
	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		**3-4**
	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 of lack of fluency		**1-2**
	Level 0 ● incorrect, inappropriate or no response		**0**

		Examples of the sort of information or ideas that might be used to support an argument: ● ion source at centre ● pair of hollow dees ● chambers evacuated ● alternating potential applied to the dees ● acceleration across gap ● high frequency ● magnetic field applied perpendicularly to chambers ● beam exits at outer region ● any appropriate formulae quoted and explained		
(b)	(i)	BQv seen mv^2/r or $m\omega^2 r$ seen v or ω given in terms of $2\pi/T$ clear correct manipulation of terms	**B1** **B1** **B1** **B1**	**4**
(b)	(ii)	neither v nor r appear in the equation	**B1**	**1**
(c)	(i)	eV seen or used ½ mv^2 seen or used $3.9(1) \times 10^6$ seen accept $v = \sqrt{\frac{2eV}{m}}$ for both first two marks	**B1** **B1** **B1**	**3**
(c)	(ii)	use or quote of equation $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ statement that γ is very close to 1 (or 0.99991 or 1.00009)	**M1** **A1**	**2**
			Total	**16**

Question 5				
(a)	(i)	mass and energy have equivalent values	**B1**	
		$E = mc^2$ mentioned	**B1**	**max 2**
		MeV is energy unit (and kg that of mass)	**B1**	
(a)	(ii)	clear attempt to substitute amu values into equation	**C1**	
		5.135×10^{-3} (u) or 4.78 (MeV) seen	**C1**	
		mass of 1 lithium nucleus = 9.98×10^{-27} (kg)	**C1**	**5**
		total number of nuclei in 1 kg = 1.00×10^{26}	**C1**	
		total energy given out = 4.78×10^{26} MeV	**A1**	
(a)	(iii)	neutrons needed (for the lithium reaction) can come from the other (deuterium-tritium) reaction	**B1**	**1**
(b)	(i)	potential energy equation ($E = \frac{Qq}{4\pi\varepsilon_0 r}$) quoted or used	**C1**	
		correct substitutions	**C1**	**3**
		$1.5(3) \times 10^{-13}$ (J)	**A1**	
(b)	(ii)	ke = 3/2 kT	**C1**	
		$0.75/0.765 \times 10^{-13}$ (J) **or** half of (b) (i) or 4×10^{9} (K) used	**C1**	**3**
		3.7×10^{9} (K) **or** total energy 1.6×10^{-13} (J)	**A1**	
(b)	(iii)	each nucleus carries a positive charge	**B1**	
		(electrostatically) repel each other	**B1**	
		strong nuclear force	**B1**	**max 4**
		this has a range of nucleus diameters	**B1**	
		high temperature needed for high kinetic energy	**B1**	
			Total	**18**

Question 6				
(a)		plutonium is toxic/large mass of plutonium	**B1**	**max 2**
		harmful if released into atmosphere/explosion occurred	**B1**	
		alphas dangerous when ingested/during launch etc	**B1**	
(b)		unaffected	**B1**	**2**
		chemical bonding involves electrons (atomic) radioactivity is nuclear (owtte)/same number of nuclei present	**B1**	
(c)	(i)	$T_{½} = \ln 2/\lambda$	**C1**	**2**
		2.51×10^{-10}	**A1**	
(c)	(ii)	molar mass calculated (0.270 kg)	**C1**	**5**
		use of 33 kg	**C1**	
		number of moles in sample (122.2)	**C1**	
		multiplication of value by Avogadro's number	**C1**	
		7.36×10^{25}	**A1**	
(c)	(iii)	(c) (i) × (c) (ii)	**C1**	**3**
		1.83×10^{16} cao	**A1**	
		Bq	**B1**	
(d)	(i)	uranium correct (234,92)	**B1**	**2**
		alpha correct (4,2) – accept He or α symbol	**B1**	
(d)	(ii)	use of 1 g generating 500 mW	**C1**	**4**
		16500 W total	**C1**	
		recognition that activity × energy of one alpha = power	**C1**	
		9.00×10^{-13} (J)	**A1**	
			Total	**20**