Version 1.0

General Certificate of Education (A-level)
January 2012

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 students' 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 students' 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 students' 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	time to halve = 0.008 s or two coordinates correct $C = T_{1/2}/(0.69 \times 150)$ or eg $0.4 = 1.4\ e^{-0.015/150C}$ 77 μF (consistent with numerical answer)	**C1** **A1** **A1**	**3**
b	**max 3 from** as capacitor discharges: pd decreases current through resistor decreases (since $I \propto V$) rate at which charge leaves the capacitor decreases (since $I = \Delta Q/\Delta t$) rate of change of charge is proportional to rate of change of pd (since $V \propto Q$) condone quicker discharge when pd is larger	 **B1** **B1** **B1** **B1** **B1**	**max 3**
c	energy stored $\propto V^2$ or use of ½ CV^2 **or** initial energy = 78.4 (or 75.5) μJ **or** final energy using V = 0.38-0.4 0 V (answer in range 5.6 – 6.4 μJ) fraction remaining = $(0.4/1.4)^2$ or 0.072 – 0.081 **or** energy lost = 72 μJ 91.8 to 92.8% lost	**C1** **C1** **A1**	**3**
d i	charge = 77 μC to 82 μC	**B1**	**1**
d ii	charge required = $77 \times 10^{-6} \times 5 \times 3.15 \times 10^{7}$ (= 12128 C) or 1A-h =3600 C 3.36(3.4) Ah	**C1** **A1**	**2**
		Total	**12**

Question 2			
a i	energy released when the separate nucleons combine to form the nucleus **or** energy needed to separate the nucleus into individual nucleons owtte	**B1**	**1**
a ii	BE in J = $8 \times 1.1314027 \times 10^{-12}$ (9.05122×10^{-12}) BE in eV = 5.6570135×10^{7} eV or BE/nucleon = 7.07×10^{6} MeV 56.570135 (MeV) (condone 3 sf consistent with electron charge)	**C1** **C1** **A1**	**3**

b i	change in BE = 0.0147120 (× 10^{-12}) J use of $E = mc^2$ with their energy 1.635 × 10^{-31} kg	C1 A1	2
b ii	use of charge on alpha particles = 2 e attempt to substitute in PE = $\frac{qQ}{4\pi\varepsilon_0 r}$ 2.4(2.39) × 10^{-13} J	C1 C1 A1	3
b iii	the mass of Be > mass of 2 He nuclei explains that when they touch there is zero KE only mass available is that of the two alpha particles extra KE provides the increase in mass of the beryllium-8 compared with the 2 He nuclei	B1 B1 B1	3
		Total	**12**

Question 3			
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		**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**

<table>
<tr><td></td><td>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
for level 3 candidates should make a significant attempt to;
explain how kinetic theory explains pressure force exerted to change momentum when molecules collide with walls; explain that work done on the gas in compression increases speed of molecules
so increases temperature and/or increases the rate of at which collisions occur; explain that reduction in volume means molecules travel less distance between collisions so increasing the rate of collisions
the answer should be easy to follow and contain few grammatical errors
for level 2, the candidate is likely may address each issue superficially or make good progress explaining cause of pressure and either temperature or pressure increase
the points being made may be made in a poorly structured response and may contain a number of grammatical errors
for level 1 candidates might relate temperature increase to molecular speed or may comment superficially on the effect of volume reduction but the response is likely to pay little regard to the physics
the answer is likely to be brief or long but hard to follow and contain many grammatical errors</td><td></td><td>1-2

0</td></tr>
</table>

b		attempt to use $\frac{pV}{T}$ = constant $\frac{1p}{483} = \frac{18 \times 1.0 \times 10^5}{308}$ $2.8(2) \times 10^6$ Pa	C1 C1 A1	3
c	i	adiabatic	B1	1
c	ii	*Q*	B1	1
d		use 4 or more cylinders timed to produce power stroke in sequence	M1 A1	2
e		P indicated correctly N indicated correctly	B1 B1	2
f		efficiency = $\frac{T_H - T_C}{T_H}$ efficiency can be increased by increasing T_H	B1 B1	2
			Total	**17**

area	
BCDAB	N
BCDEFB	P
BCDAGB	
BAEFB	

Question 4				
a	i	neutron	B1	1
a	ii	p = 36 n = 144	B1 B1	2
b	i	total energy produced = $\frac{500 \times 100}{40}$ MJ each second number of reaction = 4.2×10^{19} per second	C1 A1	2
b	ii	1 kg contains (1000/235) × 6.02×10^{23} atoms of uranium total number of fissions = (1000/235) × $6.02 \times 10^{23} \times 2 \times 10^4$ (5.1×10^{28}) time = total fissions available/number per second or 1.2×10^9 s 38.7(39) years	C1 C1 C1 A1	4

b	iii	too few neutrons produced to maintain the chain reaction probability of a neutron colliding with a uranium nucleus too low more absorption of neutrons in non-fission capture	B1 B1 B1	max 2
c		pressure = 150 × 10^5 (Pa) or $F = PA$ force on 1 cm^2 = 1500 N	C1 A1	2
d		energy removed each second $E = \frac{500 \times 100}{40}$ MJ = 1.25 × 10^9 J or $E = mc\Delta\theta$ 1.25 × 10^9 = m 5000 × 40 mass per second = 6250 kg volume per second = 8.6(8.56) m^3	C1 C1 C1 A1	4
e		**control rods** neutrons are absorbed by the nucleus of the boron/atoms **moderator** neutrons are slowed down when colliding with the protons/hydrogen nucleus	B1 B1 B1 B1	4
			Total	**21**

Question 5				
a	i	half-life is the time taken for activity to halve time for number of radioactive nuclei to fall to half original number	B1	1
a	ii	when in the body some r/a nuclei lost by excretion and other bodily functions	B1	1
a	iii	physical half life is not influenced by outside conditions is a property of an individual nucleus biological half life depend on the rate of respiration depends on how active a person is	B1 B1	2
b	i	$f = E/h$ or numerical equivalent 3.4 × 10^{19} Hz	C1 A1	2
b	ii	$\lambda = 0.69/T_{1/2}$ or numerical equivalent 3.1 × 10^{-5} s^{-1}	C1 A1	2

b	iii	'biological + physics decay constant = $3.9\times 10^{-5}\ s^{-1}$	C1	4
		$1 = 10e^{-3.9\times 10^{-5} t}$	C1	
		$\ln 0.1 = -3.9\times10^{-5} t$	C1	
		time = 5.9×10^{4} s (983 min;16.4 h)	A1	
c	i	probability of a task or activity causing harm	B1	1
c	ii	ionisation mentioned	B1	3
		radiation is used to kill cancerous cells	B1	
		risk is that radiation also damages healthy cells	B1	
c	iii	if the benefits outweigh the risks then the treatment is valid	B1	1
			Total	**17**

Question 6				
a	i	attempt to use $F = \frac{VQ}{d}$ or $E = 14800\ (V\,m^{-1})$	C1	3
		$F = 2.3 \times 10^{-15}$ (N)	C1	
		acceleration =1.39 (1.4) $\times10^{12}\ m\,s^{-2}$	A1	
a	ii	final energy = 3120 eV	B1	4
		$3120 \times 1.6(1) \times 10^{-19}$ = 4.99 or 5.02 J	B1	
		substitution of their energy in $E = 1/2\ mv^2$ with $m = 1.67 \times 10^{-27}$ (condone 1.7)	C1	
		7.67–7.74 $\times 10^{5}\ m\,s^{-1}$ (allow ecf if consistent with their energy using 2750 eV)	A1	
a	iii	use of s = (mean v)t or $v = u + at$	C1	2
		33(.4) ns	A1	
b	i	$Bev = \frac{mv^2}{r}$	B1	3
		$r = \frac{mv}{Be}$	B1	
		B, e and m are constant **or** $k = \frac{m}{Be}$	B1	
b	ii	$726000 = \frac{B \times 1.6 \times 10^{-19} \times 0.2}{1.7 \times 10^{-27}}$	C1	3
		$B = 0.0379$	A1	
		T (tesla)	B1	

c	as speed increases orbit radius increases the time to go from gap to gap remains the same in a synchrotron orbit radius is constant as speed increases *B* must increase to maintain the constant radius	**B1** **B1** **B1** **B1**	**4**
d	manufacture of radioactive isotopes for use in diagnosis and treatment eg sources do not decay whilst in transit (fresher sources) less risk in transporting radioactive materials by road use a lot of r/a materials so cheaper than buying in sources	**B1** **B1**	**2**
		Total	**21**

	UMS conversion calculator www.aqa.org.uk/umsconversion		