ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Physics 2456

Specification B: Physics in Context

PHYB5 Energy under the Microscope

Mark Scheme

2010 examination - January series

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)	(i)	the pressure is increasing at constant volume/it is being heated/temperature is rising	**B1** **B1**	**2**
(a)	(ii)	fuel is being burned/ignited	**B1**	**1**
(a)	(iii)	4 to 5	**B1**	**1**
(b)	(i)	change in internal energy	**B1**	**1**
(b)	(ii)	Q	**B1**	**1**
(b)	(iii)	the gas is compressed rapidly no heat exchange/escape of heat with surroundings owtte	**B1** **B1**	**2**
(c)	(i)	exhaust 1314 J (1310 J) useful 486 J (490 J) (however many sf used the total must be 1800 J) allow 1 for exhaust + useful = 1800 J	**B1** **B1**	**2**
(c)	(ii)	attempt to substitute data efficiency = $\frac{T_H - T_C}{T_H}$ 430 (429) K (156°C)	**C1** **A1**	**2**
(c)	(iii)	1800/34 MJ seen or calculates energy/cm^3 = 34000 (J) 0.053 (0.0529) (cm^3)	**C1** **A1**	**2**
(c)	(iv)	fuel used per second = 4 × 15 × 0.053 (= 3.18 cm^3) time 1 litre lasts = 1000/3.18 = 314 or 315 s (16.7/their (iii)) **or** 34 × 10^6 ÷ (1800 × 4 × 15) 314.8 s	**C1** **A1** **C1** **A1**	**2**
(c)	(v)	**use of** distance = speed × time (condone mixed units) 7.4 to 7.43 km ecf from (iv) (0.0236 × (iv))	**C1** **A1**	**2**
			Total	**18**

Question 2				
(a)	(i)	A to B/to the right/toward B	**B1**	**1**
(a)	(ii)	$F = BQv$	**C1**	**3**
		correct substitution	**A1**	
		4.8×10^{-15} (N)	**A1**	
(a)	(iii)	E required = 30 kV m^{-1} (31.3 if 5×10^{-15} used)	**C1**	**3**
		use of $E = V/d$	**C1**	
		540 (V) to 563 (if 5×10^{-15} used)	**A1**	
(a)	(iv)	the force produced must be opposite to the magnetic force	**B1**	**2**
		B (allow ecf from (i))	**B1**	
(b)	(i)	use of mass = $22.9 \times 1.661 \times 10^{-27}$	**C1**	**4**
		$Bqv = mv^2/r$	**C1**	
		substitution allow incorrect mass or r calculated correctly 0.114 m	**C1**	
		distance = 0.23 (0.228) (m)	**A1**	
(b)	(ii)	isotope masses differ by 3 in 15000 or 1 in 5000	**B1**	**2**
		masses differ by less than 1 in 1000 so ions cannot be separated	**B1**	
(c)		substitution in relativistic formula	**C1**	**3**
		correct to incorrect sf	**A1**	
		2.79×10^7 (m s^{-1})	**A1**	
			Total	**18**

Question 3			
(a)	correct curvature starting at (0,0) asymptotic to 2.8	**M1** **A1**	**2**
(b) (i)	use of $V = V_0 e^{-t/CR}$ (allow incorrect powers of 10) correct substitution including powers of 10 $V = 2.8e^{-550\times10^{-6}/10\times10^{-6}\times510}$ 2.5(1) (V) (may calculate Q_0, final Q and then final V)	**B1** **B1** **B1**	**3**
(b) (ii)	use of $Q = VC$ allow any voltage correct calculation of one charge with unit (or $Q = C \times 0.3$) 2.9 or 3.0 μC (allow 1 or 2 sf) 2.9×10^6 (c)	**C1** **C1** **A1**	**3**
(b) (iii)	battery capacity = 0.35 × 60 × 60 (1260 C) clear attempt using battery capacity/charge or 7.0 – 7.3 × 10^6 min or 4.2 × 10^8 s (ecf 1260/their (b) (ii)) 13.3 to 13.8 years (allow eg 13 years 10 months or 13y to 14y)	**C1** **C1** **A1**	**3**
(c)	**any 2 from** to fix the pulse frequency (condone eg to fix the heart rate) used as a timing device frequency of the pulses depends on *CR*	 **B1** **B1** **B1**	**2**
		Total	**13**

Question 4				
(a)	(i)	as a tracer to track/label elements that are used by the body	**B1**	**1**
(a)	(ii)	**any 2 from**		**2**
		gamma sources usually have short half-lives	**B1**	
		half-life is longer than usual	**B1**	
		nucleus remains in excited state for a (relatively) long time	**B1**	
(a)	(iii)	${}^{99}_{42}Mo \rightarrow {}^{99m}_{43}Tc + {}^{0}_{-1}\beta + \overline{\nu}$		**3**
		Z correct	**B1**	
		A correct	**B1**	
		antineutrino	**B1**	
(b)	(i)	use of decay constant = $0.69/T_{1/2}$ or $A = \lambda N$	**C1**	**3**
		$\lambda = 3.19 \times 10^{-5}$ (s^{-1})	**A1**	
		1.1×10^{13} atoms	**A1**	
(b)	(ii)	mass = moles × 6.0×10^{23} **or** moles = (b)(i)/6×10^{23}	**C1**	**2**
		1.8×10^{-9} g **or** 1.79×10^{-9} g	**A1**	
(b)	(iii)	**any 3 from**		**3**
		moving image has to be produced quickly	**B1**	
		moving image needs high intensity radiation/large number of photons detected per second	**B1**	
		gamma intensity decreases (exponentially) with time	**B1**	
		reference of biological half-life	**B1**	
		build up of isotope (over time) in particular regions facilitates production of static images	**B1**	
		static images can be produced by exposure of film/CCD over a long time	**B1**	
			Total	**14**

Question 5				
(a)	(i)	2	**B1**	**1**
(a)	(ii)	28.292 (MeV)	**B1**	**1**
(a)	(iii)	binding energy of 1 deuteron = 2 × 1.113 (MeV)	**B1**	**4**
		BE of **three** deuterons = 6.678 MeV	**B1**	
		increase in binding energy = (their (ii) – 6.678) (21.6) (MeV)	**B1**	
		their MeV × 1.6 × 10^{-13} (J) (3.46 × 10^{-12} J)	**B1**	
(b)	(i)	**any 4 from**		**4**
		deuterons (and tritium) are positively charged	**B1**	
		there is a repulsive force between the deuterons (or between deuterons and tritium)	**B1**	
		potential energy increases as the deuterons approach each other or KE falls as they approach	**B1**	
		binding energy of tritium is less than that of two deuterons	**B1**	
		energy input is needed	**B1**	
		deuterons will have higher energy at higher temperatures	**B1**	
		need to be close as strong force is short range	**B1**	
(b)	(ii)	**any 4 from**		**4**
		fission uses uranium	**B1**	
		uranium supply is limited	**B1**	
		fission reaction produces radioactive waste	**B1**	
		deuterons are plentiful in water/almost limitless supply of fuel	**B1**	
		energy released for given mass of fuel is greater	**B1**	
		risk reduced	**B1**	
		with example (radiation leak/meltdown/possible explosion)		
			Total	**14**

Question 6			
(a) (i)	$1.2 \times 10^{11} \times 7 \times 10^{12}$ s energy = 8.4×10^{23} eV 134 kJ 1.34×10^{5} (J)	C1 C1 A1	3
(a) (ii)	time taken in stationary frame of reference = 9.0×10^{-5} s use of $t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ 1.27 μs (given to 3 or more sfs)	B1 B1 B1	3
(b)	idea of KE changing into mass of new particles two beams give twice the KE available **or** when two beams collide head-on all KE of colliding particles converted	B1 B1	2
(c) (i)	correct substitution in $Pv = NkT$ number per m³ = 3.81×10^{14} 10^6 cm³ = 1 m³ so number per cm³ = 3.81×10^{8} = 381 million **or** correct substitution in $pV = nRT$ number of moles = 6.36×10^{-10}; $\times 6.02 \times 10^{23}$ 10^6 cm³ = 1 m³ so number per cm³ = 3.81×10^{8} = 381 million	B1 B1 B1 B1 B1 B1	3
(c) (ii)	$p = \frac{1}{3}mn \langle c^2 \rangle$ or $pV = \frac{1}{3} Nm \langle c^2 \rangle$ or $\frac{1}{2} m\langle c^2 \rangle = \frac{3}{2} kT$ $1 \times 10^{-8} = 0.33 \times 4.8 \times 10^{-26} \times 400 \times 10^{12} \langle c^2 \rangle$ or $\langle c^2 \rangle$ = 1563 to 1578 or 1640 to 1657 39.5 – 39.7 or 40.5 (m s^{-1}) not 41	C1 C1 A1	3
(d)	resistance falls as temperature is lowered at the critical temperature resistance falls to/becomes zero **or** is zero at and below this temperature	B1 M1 A1	3

(e)	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 candidates QWC in this answer will be one of the criteria used to assign a level and award the marks for this question.		
	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**
	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		**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 answer: • pressure caused by momentum change of molecules colliding with walls • momentum change depends on speed of molecules • more molecules per sec means increased pressure • evacuation reduces number of molecules in gas so fewer colliding • lower temperature reduces the speed of the molecules • each molecule collides less often with walls • change in momentum per collision is lower for higher band must address issues of evacuation and cooling and include comments on how pressure is produced		
		Total	**22**