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General Certificate of Education (A-level)
June 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	**max four from**		
	first law terms clearly identified	**B1**	
	heat transferred to the system by engine (E)	**B1**	
	internal energy rises (E)	**B1**	**max 4**
	heat transferred from the system by radiator (R)	**B1**	
	internal energy falls (R)	**B1**	
	work done on the system by pump or negligible	**B1**	
b i	mass of coolant 10.2 (10.18) (kg)	**B1**	**4**
	use of $Q = mc\Delta\theta$	**B1**	
	8°C temp change	**B1**	
	2.9×10^5 or 2.95×10^5 (J)	**B1**	
b ii	flow rate 2.25×10^{-3} kg s^{-1} **or** 844 cycles h^{-1} **or** 0.234 cycles s^{-1}	**C1**	**3**
	time for one cycle = 4.27 s **or** 844 × bii/3600 **or** 0.234 × bii	**C1**	
	range 67-70 kW	**A1**	
b iii	conversion of one temperatures to kelvin (384 or 288 or 369)	**C1**	**4**
	one value of energy divided by temp in K (766 → 781 & 1020 → 1040)	**C1**	
	range 256-260	**A1**	
	J K^{-1}	**B1**	
b iv	increase	**M1**	**2**
	entropy of coolant falls and of air rises/entropy of universe **or** overall entropy or 'it' always increases	**A1**	
		Total	**17**

Question 2			
a	'it' or nucleus or atom or nuclide is excited	**B1**	**2**
	longer lived than normal (for gamma emitter) or for long time	**B1**	
b i	decay constant calculated or substituted into decay equation directly (0.115 hour^{-1} or 3.2×10^{-5} s^{-1})	**C1**	**4**
	correct substitution into decay equation (exp(–0.155 × 20))	**A1**	
	0.096 remaining (0.100 if ln 2 used)	**B1**	
	manipulation and approximation to 90% decayed	**B1**	

b	ii	conversion from keV into joules (2.24×10^{-14}) rearrangement of or substitution into $E = hf$ 8.84×10^{-12} (m) or 8.88×10^{-12} (m)	C1 C1 A1	3
b	iii	equivalent wavelength to X-rays/well-known/understood technology/ photo plates etc high activity/many γs emitted **s^{-1}**	B1 B1	2
b	iv	**max three from** **γs poor ionisers** so little absorption or little harm to cells ^{99m}Tc has high initial activity or emits lots of γs per second at start only a small dose of ^{99m}Tc need be administered **^{99}Tc has low activity** so few βs per second/low radiation level γs are low energy (140 keV not as energetic as other γs) biological half-life relatively short	 B1 B1 B1 B1 B1 B1	max 3
c		$^{99}_{43}\text{Tc} \rightarrow {}^{99}_{44}\text{Ru} + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}$ correct proton and nucleon numbers for Tc correct proton and nucleon numbers for Ru correct proton and nucleon numbers for beta antineutrino included (condone no numbers)	 B1 B1 B1 B1	4
			Total	**18**

Question 3				
a	i	protons accelerate in gaps/between drift tubes protons travel at constant speed in(side) drift tubes electric field/electrostatic field/pd between drift tubes (allow positive tube repels and negative attracts as long as no reference to tubes being charged)	B1 B1 B1	3
a	ii	longer tubes when protons are travelling faster allows use of constant frequency supply (or constant period/time in tubes)	B1 B1	2
b	i	24 × 35 kV shown or 840 (kV) $eV = \frac{1}{2}mv^2$ or $v = \sqrt{\left(\frac{2eV}{m}\right)}$ correct substitution for e and m and V = 35 kV or 24/25 × 35 kV 1.27×10^{7} (m s^{-1})	B1 B1 B1 B1	4

b ii	recognition that v/c = 0.042 or v^2/c^2 = 1.8 × 10^{-3}	C1	3
	comment relating to $\sqrt{1-\frac{v^2}{c^2}}$ eg = 0.999 (or γ = 1.0009)	A1	
	no reason to use relativistic correction (do not allow ecf for conclusion from wrong use of equation eg not squaring)	B1	
		Total	**12**

Question 4			
a i	magnetic field shown covering whole tube (allow velocity selector too)	B1	1
a ii	out of (plane of) page (not 'upward'/'up')	B1	1
b	BQv or Bev	M1	4
	mv^2/r	M1	
	recognition that m ∝ r (smallest mass deflected most)	A1	
	thus X detects ion of relative mass 24u (allow 24)	B1	
c	method of taking ratios/use of all three isotopes	C1	3
	24.3	C1	
	2.43 × 10^{-2} (kg)	A1	
d i	ratio E/B see or $EQ = BQv$	C1	2
	2.24 × 10^4 (m s^{-1})	A1	
d ii	charge cancels in equation (no charge in equation)	M1	2
	has no effect	A1	
d iii	r smaller/greater curvature/curve tighter	C1	2
	r halved/r decreases by (factor of) 2	A1	
		Total	**15**

Question 5			
a i	mass defect = difference in mass of nucleus (atom) and that of sum of its nucleons (parts/components/particles)	B1	3
	(difference) equivalent to binding energy/energy needed to separate nucleus into individual nucleons	B1	
	reference to $\Delta E = \Delta mc^2$	B1	
a ii	${}^4_2\text{He}$ has a binding energy per nucleon of 7.1 (or 7.0) MeV **and** ${}^2_1\text{H}$ of 1.1 (or 1.2) MeV	C1	3
	multiply one value by 4 (28.0 or 28.4/4.4 or 4.8 etc)	C1	
	total energy released = 23.2 – 24.0 (MeV)	A1	

a	iii	**max three from** hydrogen nuclei/^2_1H are positively charged need to overcome (electrostatic) **repulsion** need to be very close/nuclear dimensions for **strong nuclear force** to act (high temperature mean) nuclei have large **kinetic** energies/ velocities/speeds (credit ½ $m\langle c^2\rangle = 3/2\,kT$)	B1 B1 B1 B1	max 3
a	iv	$E_P = Q_1Q_2/4\pi\varepsilon_0 r$ substituted values $\frac{(1.6\times10^{-19})^2}{4\pi\times8.85\times10^{-12}\times1.5\times10^{-15}}$ 1.53×10^{-13} (J)	B1 B1 B1	3
b		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 **Examples of the sort of information or ideas that might be used to support an argument:** **Definition of plasma** ● plasma (positively charged) nuclei and (free) electrons or protons + neutrons + electrons **not** ions allow gas in which electrons have been stripped from atoms to access 5 (not 6) **Problems** ● heating to high enough temperature ● confining plasma for long enough to fuse ● getting a high enough density of plasma ● touching sides of container cools plasma ● high neutron flux released – harmful and causes other materials to become radioactive ● tritium radioactive **Solved by** ● heating deuterium-tritium mixture ● laser/high current heating ● absorption of (rf) e-m radiation ● neutral beam heating by injection of neutral deuterium atoms ● magnetic field from large coils around torus ● currents magnetic field give pinch effect helps confine plasma		**0**
		Total	**18**

Question 6				
a		ratio of charge to potential/voltage/pd etc	**B1**	**1**
b	i	**max three from** charge (on C) increases with pd or time current or rate of charging decreases with charge/pd/time when fully charged $I = 0$ or $V_c = E$ at other times $V_c = E - V_r$ or $V_c = E - IR$ in words or symbols	 **B1** **B1** **B1** **B1**	**max 3**
b	ii	curve drawn above given curve starting at (0,0) asymptotic to E	**M1** **A1**	**2**
c	i	in series so that the total voltage adds to make 650 V	**M1** **A1**	**2**
c	ii	equates ½ CV^2 to 32 J or $Q = 9.8 \times 10^{-2}$ (C) 1.51×10^{-4}	**B1** **B1**	**2**
c	iii	RC = 0.077 (or 77) s (or m s)	**B1** **B1**	**2**
c	iv	substitution of values into decay equations ecf from biii use of logs 0.50 (s)	**C1** **C1** **A1**	**3**
d	i	too high a voltage will cause insulation/capacitor to break down capacitor now conducts/short circuit/does not store charge/charge leaks (across capacitor) allow 1 mark for argument that more energy would be stored (than required and potential harm to patient/possible overheating)	**B1** **B1**	**2**
d	ii	implanted devices small/convenient/portable/improved quality of life for user (no external paraphernalia)/avoids (frequent) hospital visits **plus any two from** designed to have long-life components/batteries/not fail easily breakdown would mean immediate surgery battery needs changing rejection/corrosion problems	**B1** **B1** **B1** **B1** **B1**	**max 3**
			Total	**20**

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