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General Certificate of Education (A-level)
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Physics A PHA5C

(Specification 2450)

Unit 5C: Nuclear and Thermal Physics
Applied Physics

Final

Mark Scheme

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Section B – Applied Physics

Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)	(i)	8.3 rev = 8.3 × 2π rad ✓ (= 52 rad) Use of $\omega_2^2 = \omega_1^2 + 2\alpha\theta$ $0 = 6.4^2 + 2 \times \alpha \times 52$ ✓ **OR** use of $\theta = ½(\omega_1 + \omega_2)t$ leading to t = 16.25 s *and* $\omega_2 = \omega_2 + \alpha t$ α = (-) 0.39 ✓ rad s^{-2} ✓	4	If eqtn(s) of motion used correctly with θ = 8.3 (giving α = 2.5), give 2 out of first 3 marks. Accept : s^{-2} Unit mark is an independent mark
1	(a)	(ii)	$T = I\alpha$ $= 8.2 \times 10^{-3} \times 0.39 = 3.2 \times 10^{-3}$ N m ✓	1	Give CE from a i
1	(b)	(i)	($W = T\theta$ *or* $W = T\omega t$) where $\theta = 0.78 \times 270$ √ (= 210 rad) $= 3.2 \times 10^{-3} \times 210 = 0.67$ J ✓	2	Give CE from a ii
1	(b)	(ii)	ratio = $\dfrac{900 \times 270}{0.67}$ or $\dfrac{2.4(3) \times 10^5}{0.67}$ ✓ = 3.6×10^5 ✓	2	CE from b i. Must be in the form: number × 10^5 with number calculated correctly. 900 × 270 or 2.4(3)× 10^5 or equivalent must be seen for 1st mark 1 mark for <u>only</u> writing 3.6×10^5
2	(a)		<u>Use of</u> $I = \Sigma mr^2$ or expressed in words ✓ With legs close to chest, more mass at smaller r, so I smaller ✓	2	
2	(b)	(i)	Angular momentum is conserved/must remain constant **OR** no external torque acts √ as I decreases, ω increases and vice versa to maintain $I\,\omega$ constant ✓ OR as I varies, ω must vary to maintain $I\,\omega$ constant	2	WTTE

2	(b)	(ii)	(Angular velocity increases initially then decreases (as he straightens up to enter the water)). With one detail point e.g. ✓ • Angular velocity when entering water is greater than at time t = 0 s. • Angular velocity increases, decreases, increases, decreases • Maximum angular velocity at t = 0.4 s • Greatest rate of change of ang. vel. is near the start • Angular velocity will vary as inverse of M of I graph	1	No mark for just ang. vel starts low then increases then decreases, i.e. for describing ω only at positions 1,2 and 3.
2	(c)		angular. momentum = $10.9 \times 4.4 = 48$ (N m s) ✓ (ω_{max} occurs at minimum I) minimum $I = 6.4$ kg m^2 (at 0.4 s) ✓ $6.4 \times \omega_{max} = 48$ leading to $\omega_{max} = 7.5$ rad s^{-1} ✓	3	Allow 6.3 to 6.5. If out of tolerance e.g. 6.2 give AE for final answer
3	(a)		(Adiabatic change requires) no heat transfer / energy transfer / heat to escape / heat loss (to surroundings) ✓ (Compression stroke occurs in short time/very quickly) so no time for heat transfer ✓ (Therefore change can be considered to be adiabatic)	2	Do not accept heat or energy 'change' .
3	(b)	(i)	$P_1V_1^{\gamma} = p_2V_2^{\gamma}$ $1.0 \times 10^5 \times (4.5 \times 10^{-4})^{1.4} = 6.2 \times 10^6 \times V_2^{1.4}$ ✓ $V_2 = 2.4 \times 10^{-5}$ m^3 ✓ 2 sig fig ✓	3	Significant figure mark is an independent mark

3	(b)	(ii)	use of $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ $T_2 = \frac{p_2V_2T_1}{p_1V_1} = \frac{6.2 \times 10^6 \times 2.4 \times 10^{-5} \times 297}{1.0 \times 10^5 \times 4.5 \times 10^{-4}}$ ✓ OR use of $n = p_1V_1/RT_1$ and $T_2 = p_2V_2/nR$ Leading to $T_2 = 982$ K ✓	2	CE from b i If 2.36×10^{-5} m^3 used for V_2, $T_2 = 966$ K

3	(b)	(iii)	So that the fuel has partially evaporated/started to burn when piston is at top of stroke (so max pressure obtained when piston is at top of stroke/top dead centre). OR If injected at top dead centre. by the time fuel has started to burn, piston would be on its way down cylinder, (so max possible pressure not obtained).	1	Accept 'diesel' instead of 'fuel'

3	(c)		**Good – Excellent** The information conveyed by the answer is clearly organized, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The candidate gives a comprehensive account of the differences between the two cycles, **with reasons**. There are clear statements relating to the need for induction and exhaust processes/strokes in a real engine only, that adiabatic processes are not possible in the real engine, that constant pressure and constant volume processes are impossible, and/or that the corners of the real engine diagram are rounded.* *They will refer to the lower efficiency of the real engine, linking this to the smaller area loop, or the fact that the pumping loop has to be subtracted from the main loop and/or that heat transfers occur during compression and expansion and that in the real engine friction has to be overcome/power has to be expended in driving ancillaries.*	Mark Range 5-6	

			Modest – Adequate The information conveyed in the answer may be less well organized and not fully coherent. There is less use of specialist vocabulary or specialist vocabulary may be used or spelled incorrectly. The form and style of writing is less appropriate. *The candidate's comparisons are less complete but good understanding is shown of some of the major differences between the diagrams, with some reasons given.* *They should be able to give at least one valid reason for the lower efficiency of the real engine cycle.* **Poor – Limited** The information conveyed by the answer is poorly organized and may not be relevant or coherent. There is little correct use of specialist vocabulary. *The candidate is more likely to describe the differences rather than explain them. They are likely to make reference to the rounded corners, and the induction/exhaust strokes in the 'real' diagram, but not be able to say why these do not exist in the theoretical diagram. They may not be able to give a valid reason for the lower efficiency of the real engine cycle, or may give vague reasons in terms of 'heat losses' or 'friction' without further detail.* **The descriptions and explanations expected in a good answer should include several of the following physics ideas** ▪ Real engine needs 'pumping loop' at near atmos. pressure for induction and exhaust ▪ Work needed for induction and exhaust –so efficiency lower than theoretical ▪ Area of pumping loop has to be subtracted from main loop, hence reducing net work and hence efficiency of real engine ▪ Theoretical cycle needs no pumping loop/same air continuously taken through repeated cycles	3-4 2-1	

			▪ Corners rounded on real engine diagram [because valves are needed and take finite time to open/close] ▪ Cooling cannot occur at constant volume in real engine [because piston would have to stop] ▪ Heating does not occur at constant pressure [because impossible to control rate of burning of fuel during injection] ▪ Compression and expansion do not take place infinitely quickly heat is lost; therefore not adiabatic processes, lowering efficiency ▪ Area of loop is smaller for real engine, less work done per cycle so lower efficiency ▪ Friction between moving surfaces has to be overcome /energy expended in driving oil and water pumps, opening and closing valves etc. ▪ Always some exhaust gases present in cylinder. ▪ Theoretical cycle does not make reference to any mechanism ▪ Calorific value of fuel is never fully realised		

4	(a)		(A device in which) an input of work ✓ (causes) heat to transfer from a cold space/reservoir to a hot space/reservoir ✓	2	

4	(b)		Heat transfer to hot space equals work done plus heat transfer from cold space/ $Q_{IN} = W + Q_{OUT}$ so Q_{IN} (is always) > Q_{OUT} *reason must be seen* ✓ $COP_{HP} = \frac{Q_{IN}}{W}$ and $COP_{REF} = \frac{Q_{OUT}}{W}$ So $COP_{HP} > COP_{REF}$ ✓ **OR** $Q_{IN} = W + Q_{OUT}$ ✓ $COP_{HP} \times W = W + COP_{REF} \times W$ *or* $COP_{HP} = \frac{Q_{IN}}{W} = \frac{W + Q_{OUT}}{W}$ So $COP_{HP} = 1 + COP_{REF}$ *So* $COP_{HP} > COP_{REF}$ ✓	2	Either written statement or expressed in symbols The COP formulae are in formulae booklet so no marks for simply quoting them. i.e 2nd mark cannot be awarded without first mark.