A-LEVEL
PHYSICS A
PHA5C – Applied Physics
Mark scheme

2450
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Question	Answers	Additional Comments/Guidance	Mark	ID details
1 a	$\frac{3.5}{(2\pi \times 0.088)}$ = 6.3 rev 6.3 × 2π = 39.8 rad or 40 rad ✓ OR $\frac{3.5}{0.088}$ = 39.8 or 40 rad ✓	If correct working shown with answer 40 rad give the mark Accept alternative route using equations of motion.	1	
1 b	$\omega = v/r$ =2.2/0.088 = 25 rad s^{-1} ✓		1	
1 c i	$E = ½I\,\omega^2 + ½mv^2 + mgh$ = $(0.5 \times 7.4 \times 25^2)$ + $(0.5 \times 85 \times 2.2^2)$ + $(85 \times 9.81 \times 3.5)$ = 2310 ✓ + 206 ✓ + 2920 ✓ (= 5440 J or 5400 J)	CE from 1b $½\,I\,\omega^2 + ½mv^2$ = 2310 + 210 = 2520 J $½\,I\,\omega^2 + mgh$ = 2310 + 2920 = 5230 J $½mv^2 + mgh$ = 210 + 2920 = 3130 J Each of these is worth 2 marks	3	
1 c ii	Work done against friction = $T\theta$ = 5.2×40 = 210J ✓ Total work done = W = 5400 + 210 = 5600J ✓ 2 sig fig ✓	CE if used their answer to 1 c i rather than 5400J Accept 5700 J (using 5440 J) Sig fig mark is an independent mark	3	

1 d	Time of travel = distance /average speed = 3.5/1.1 =3.2 s ✓ $P_{ave} = \frac{5600}{3.2} = 1750$ W $P_{max} = P_{ave} \times 2 = 3500$ W ✓ **OR** accelerating torque = $T = W/\theta$ = 5600/40 = 140 N m ✓ P = $T\,\omega_{max}$ = 140× 25 = 3500 W ✓	CE from 1c ii 1780 W if 5650 J used	2	

question	answers	extra information	mark
2			6

Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information on page 4 and apply a ‘best-fit’ approach to the marking.

0 marks	Level 1 (1–2 marks)	Level 2 (3–4 marks)	Level 3 (5–6 marks)
The information conveyed by the answer is sketchy, and neither relevant or coherent. *The candidate shows inadequate understanding of the concept of moment of inertia. Formulae may be quoted from the Formulae booklet, but the candidate is unable to apply their meaning to the question.*	The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. *The candidate shows little understanding of how M of I affects acceleration, probably confusing energy, momentum or torque, or treating this part of the question cursorily. They will probably relate M of I to mass and radius, but not cover the aspects of mass, and distribution of mass around the axis, and may not relate their answers well to the context of the question.* *<u>There will be consideration of any 2 or 3 of the answer points below</u>*	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. *Some attempt may be made to link energy, torque or momentum to acceleration, but understanding will be limited. They will link M of I to mass and radius^2 but may not cover all aspects of mass, and distribution of mass around the axis. They are likely to be able to suggest means of reducing M of I.* *<u>At least any 4 of the answer points below are covered,</u>*	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 can explain the need for a low M of I for high acceleration by arguing coherently in terms of energy **or** torque **or** momentum, or a combination of these. They will relate their answer to cycles , and possibly specific sports.* *The candidate will show how $I = mr^2$ influences wheel design for low inertia, covering mass, and distribution of mass around the axis. They may also discuss optimizing low inertia with wheel strength or other design constraints.* *<u>The answer includes at least one of the first 3 answer points below and any 5 others.</u>*

examples of the points made in the response	**extra information**
▪ Kinetic energy = ½$I\ \omega^2$ so low I gives low stored energy, so less power needed to bring wheels (hence cycle) up to speed	.
▪ Torque: $T = I\alpha$ so large torques needed (high push on pedals) unless I is small OR $T = I\alpha$ so for given torque low I means high acceleration.	
▪ Momentum: $T = \Delta (I\ \omega)$ /time, so unless I small large time needed to bring to given angular speed for given torque	Must relate $I\omega$ to torque
▪ $I = \Sigma mr^2$ explained AND/OR I depends on how mass is distributed	
▪ So for low I, low m / low density materials needed	Accept 'lightweight' for 'low density'
▪ of high strength e.g. carbon fibre	Either or both of high strength and named low density material
▪ For low I, small radius helps, (but limited by design needs)	e.g. gearing or pedalling problems
▪ So low I if most of mass is near axle, and little mass far from axle	
▪ Hence use narrow tyres, low mass rims and tyres, spoke tensioners at hub etc…..	Do not credit answers in terms of friction at the bearings.
▪ clearly relates linear acceleration to angular acceleration *($a = r\alpha$)*	Even though this last point is not on the specification

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 a i	Clear statement that for isothermal pV =constant or $p_1V_1 = p_2V_2$ ✓ Applies this to any 2 points on the curve AB ✓ e.g. $1.0 \times 10^5 \times 1.2 \times 10^{-3} = 4.8 \times 10^5 \times 0.25 \times 10^{-3}$ $120 = 120$	Allow $pV = c$ applied to intermediate points **estimated** from graph e.g. $V = 0.39 \times 10^{-3}$, $p = 3 \times 10^5$	2	
3 a ii	$W = p\,\Delta v$ $= 4.8 \times 10^5 \times (0.39 - 0.25) \times 10^{-3}$ $= 67$ J ✓		1	
3 b	see table below	Any horiz line correct up to max 3. Give CE in B → C if ans to 3 a ii used for *W* <u>If no sign take as +ve.</u>	max 3	

	Q/J	W/J	ΔU/J	
process A → B	-188	-188	0	✓
process B → C	+235	(+)67	(+)168	✓
process C → A	0	+168	-168	✓
whole cycle	+47	+47	0	✓

3 c	$\eta_{overall}$ = 47/235 = 0.20 or 20% ✓		1	
3 d	Isothermal process would require engine to run very slowly/ be made of material of high heat conductivity ✓ Adiabatic process has to occur very rapidly / require perfectly insulating container / has no heat transfer ✓ Very difficult to meet both requirements in the same device. ✓ Very difficult to arrange for heating to stop exactly in the right place (C) so that at end of expansion the curve meets the isothermal at A. ✓	Do not credit bald statement to effect adiabatic/isothermal process not possible - must give reason. Ignore mention of valves opening/closing, rounded corners, friction, induction /exhaust strokes. wtte	max 2	
Total			9	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4 a	The ratio $\dfrac{\text{energy given to hot space/area to be heated}}{\text{work input}}$ ✓ OR COP = Q_{IN}/W with Q_{IN} and W explained/defined ✓	It must be clear that Q_{IN} is energy delivered to the area to be heated/hot space. Do not accept 'heat input' or any wording that is vague.	1	
4 b i	$\eta_{max} = \dfrac{1600 - 290}{1600} = 0.82/82\%$ ✓ input power = $\dfrac{\text{output power}}{\text{efficiency}} = \dfrac{80}{0.82}$ = 98 kW ✓ fuel flow rate × CV = 98 kW fuel flow rate = 98000/(49 × 10^6) = 2.0 × 10^{-3} ✓ kg s^{-1} ✓ OR 7.2 ✓ kg h^{-1} ✓	If first 2 steps in calculation are not seen and 80 kW used for input power give 1 mark for: fuel flow rate = 80000/(49 × 10^6) = 1.6 × 10^{-3} ✓ The unit mark is an independent mark.	4	
4 b ii	$COP_{HP} = \dfrac{Q_2}{W}$ So Q_2 =16 × 2.6 = 41.6 or 42 kW ✓ Q_1 = 98 – 80 = 18 kW ✓ Total $Q_1 + Q_2$ = 60 kW ✓	CE for Q_1 if incorrect input power from b i is used, but NOT 80 -16 or 80 - 80	3	
4 b iii	Heat pump delivers more heat energy than the electrical energy input. ✓		2	

	Reason: it <u>adds</u> energy from external source to electrical energy input. ✓	Accept $Q_{IN} = W + Q_{OUT}$ if explained correctly e.g. by diagram.		