A-LEVEL
Physics
PHA5/2C – Applied Physics
Mark scheme

2450
June 2017

Version: 1.0 Final

Mark schemes are prepared by the Lead Assessment Writer 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 associates 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 associate understands and applies it in the same correct way. As preparation for standardisation each associate 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, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

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.

Further copies of this mark scheme are available from aqa.org.uk

Question	Answers	Additional Comments/Guidance	Mark	ID details
1 (a)	✓ against 'thin ring'		1	
1 (b) (i)	(as core radius decreases M of I of core decreases) $I\ \omega$/angular momentum must remain constant ✓ I decreases so ω increases and greater ω means shorter period of rotation or less time for one revolution ✓		2	
1 (b) (ii)	$0.4\ mR_1^2 \times 2\pi/T_1 = 0.4\ mR_2^2 \times 2\pi/T_2$ ✓ $T_2/T_1 = R_2^2/R_1^2$ ✓ $T_2 = \frac{(14 \times 10^3)^2}{(5.3 \times 10^7)^2} \times 5.9 \times 10^6$ = 0.41 s ✓ 2 sf ✓ **OR** $\omega_1 = 2\pi/T = 2\pi/(5.9\times 10^6) = 1.1 \times 10^{-6}$ rad s^{-1} ✓ (1.07×10^{-6}) rad s^{-1} $0.4\ m \times (5.3 \times 10^7)^2 \times \omega_1 = 0.4\ m \times (14 \times 10^3)^2 \times \omega_2$ ✓ leading to ω_2 = 16 rad s^{-1} [15.3 if 1.07×10^{-6} used] $T_2 = 2\pi/\omega_2$ = 0.39 s (2 sf throughout) ✓ 2 sf ✓ [0.41 s if 1.07×10^{-6} rad s^{-1} and 15.3 rad s^{-1} used]	$I_1\omega_1 = I_2\omega_2$ not enough for second mark Must see substitution The sf mark is an independent mark and can only be given if final answer is 2 sf.	4	
Total			**7**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
2 (a) (i)	$\Delta E = ½ I (\omega_1^2 - \omega_2^2) = 0.5 \times 0.041 \times (6700^2 - 3300^2)$ $= 700 \times 10^3$ J ✓ $(697 \times 10^3$ J)		1	
2 (a) (ii)	$P = E/t = \frac{700 \times 10^3}{7.2}$ = 97 000 W ✓ **OR** Use of $T = I\alpha$ *and* $P = T\omega_{ave}$ giving 97 000 W ✓	Give CE for use of 2ai answer provided $½ I \omega^2$ has been used e.g $½ I \omega_{AVE}^2$ or $½ I \omega_1^2$ or $½ I (\omega_1 - \omega_2)^2$ Accept 97 kW if unit is changed in answer line from W to kW.	1	
2 (a) (iii)	$T = P/\omega_{ave} = \frac{97\times 10^3}{5000}$ = 19 ✓ N m ✓ **OR** $T = I\alpha = 0.041 \times \frac{(6700-3300)}{7.2}$ = 19 ✓ N m ✓	The unit mark is an independent mark. Award first mark if *T* has been correctly calculated in 2aii if alternative method used in 2aii.	2	
2 (b)			Max 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.

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*	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 the factors which affect energy storage in a flywheel.*	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 may not tackle all of the*	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. *All three bullet points will be addressed. Answers will relate E_K to the factors that give high M of I, with sensible suggestions*

booklet, but the candidate is unable to apply their meaning to the question.	*They may relate rotational E_K to angular speed and/or M of I, but not confidently cover aspects of mass, and distribution of mass around the axis, and may not relate their answers well to the context of the question.*	*bullet points in the question fully, but should have a fairly good idea of the factors that affect energy storage. Candidates are likely to relate E_K to angular speed^2 and to the way the mass is distributed around the axis.*	*concerning the shape and design.*

examples of the points made in the response	**extra information**
• E_K proportional to ω^2 • E_K proportional to I <u>Shape</u> • I depends on mass and distribution of mass around axis. • $I = \Sigma mr^2$ so arrange more m at outer edge of flywheel • By using heavy rim and spokes/thin centre web • Increase thickness to increase m <u>Material</u> • use higher density material • Gives greater mass for given size • use material of higher tensile strength • for higher speeds without bursting/to withstand rotational/centripetal stresses <u>Design for high ω</u> Increase ω by: • Reduce friction at bearings • use lubrication or roller bearings/air bearings/magnetic bearings	Also allow • sketches which convey correct info clearly • use of 'depends on' for 'proportional to' • need for perfect balance • gyroscopic effects *Level 3: 1st 2 points plus 6 other points from shape, material and design for high ω* *Level 2: between 4 and 7 points* *Level 1 fewer than 4 points.* *Quoting formulae alone is not enough.*

	• smooth outer surfaces • small increase in ω gives large increase in E_K (because ω^2)			

Total			**10**

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 (a) (i)	use of $p_1V_1^{\gamma} = p_2V_2^{\gamma}$ (gives $p_2 = p_1\left(\frac{V_1}{V_2}\right)^{\gamma}$) $p_2 = (1.0\times10^5)\left(\frac{5.8\times10^{-6}}{2.3\times10^{-7}}\right)^{1.4}$ ✓ $= 9.2\times10^6$ Pa ✓	First mark for correct substitution of data into $p_1V_1^{\gamma} = p_2V_2^{\gamma}$ or $p_2 = p_1\left(\frac{V_1}{V_2}\right)^{\gamma}$ Second mark for arriving at correct answer to more than 1 sf.	2	
3 (a) (ii)	Use of $n = \frac{p_1V_1}{RT_1}$ ✓ $= \frac{1.0\times10^5\times5.8\times10^{-6}}{8.31\times293}$ $= 2.4\times10^{-4}$ mol ✓ (2.38×10^{-4} mol)		2	

3 (a) (iii)	(use of $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ or use of n, p_2 and V_2 in $pV = nRT$ gives) $T_2 = \frac{(9.2\times10^6)\times(2.3\times10^{-7})\times293}{(1.0\times10^5)\times(5.8\times10^{-6})}$ ✓ = $1070\,\text{K}$ ✓ $(1068\,\text{K})$ $\left[\text{or } T = \frac{(9.2\times10^6)\times(2.3\times10^{-7})}{2.4\times10^{-4}\times8.31}\right]$	Allow use of 9 × 10^6 for p_1	2	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 (b)	$Q = \Delta U + W$ with symbols explained ✓ (if plunger pushed in slowly), sufficient time for heat transfer to surroundings/tube/metal plug ✓ (so) any increase in Δ*U* will be zero or small ✓ [or Δ*U* = 0] relates Δ*U* to temperature increase ✓		Max 3	
Total			**9**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4 (a) (i)	w.d. = area of loop ✓ suitable method for finding area e.g. counting squares ✓ scaling factor calculated leading to 215×10^3 J ✓ allow 195×10^3 J to 232×10^3 J	1st mark can be awarded if it is clear from Figure 6 that correct area is used, or if working leads to correct answer Allow 15½ to 18½ 1 cm squares, or 390 to 465 small squares. e.g. 430 small squares × (0.05×10^5) × 0.1 or 17 1 cm squares × (0.25×10^5) × 0.5	3	
4 (a) (ii)	$215 \times 10^3/5.9 = 36 \times 10^3$ W ✓	Allow CE for (answer to (a)(i)) ÷ 5.9	1	
4 (b) (i)	output power = *mgh/t* = (5700 × 9.8 × 2.1)/5.9 = 20×10^3 W ✓		1	
4 (b) (ii)	mechanical efficiency = output power/indicated power = 20/36 = 0.56 (56%) ✓	Allow CE for [answer (b) (i)] / [answer (a) (ii)] provided answer < 100%	1	
4 (c) (i)	$\eta_{max} = \frac{T_H - T_C}{T_H}$ $= \frac{375 - 285}{375}$ = 0.24 (24%) ✓		1	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4 (c) (ii)	**Any 2 from** • heat loss through cylinder wall or piston to surrounding air • cylinder and piston have to be heated from cold every cycle • cold cylinder walls will condense some of the input steam • leakage of steam or air past piston • not all steam may be condensed • friction (max 1 mark) – but must say where e.g. piston/cylinder pivot/beam in pump	Answers must relate to this engine. Do not credit general answers such as 'heat loss to surroundings' or 'friction in moving parts'	Max 2	
Total			**9**	