AQA

A-level
PHYSICS
7408/3BC

Paper 3 Section B Engineering physics

Mark scheme

June 2023

Version: 1.1 Final

2 3 6 A 7 4 0 8 / 3 B C / M S

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 Examiner.

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

Physics - Mark scheme instructions to examiners

1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the Examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

2. Emboldening

2.1 In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.
2.2 A bold **and** is used to indicate that both parts of the answer are required to award the mark.
2.3 Alternative answers acceptable for a mark are indicated by the use of **or**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

3. Marking points

3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which candidates have provided extra responses. The general principle to be followed in such a situation is that 'right + wrong = wrong'.

Each error / contradiction negates each correct response. So, if the number of errors / contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

3.2 Marking procedure for calculations

Full marks can usually be given for a correct numerical answer without working shown unless the question states 'Show your working'. However, if a correct numerical answer can be evaluated from incorrect physics then working will be required. The mark scheme will indicate both this and the credit (if any) that can be allowed for the incorrect approach.

However, if the answer is incorrect, mark(s) can usually be gained by correct substitution / working and this is shown in the 'extra information' column or by each stage of a longer calculation.

A calculation must be followed through to answer in decimal form. An answer in surd form is never acceptable for the final (evaluation) mark in a calculation and will therefore generally be denied one mark.

3.3 Interpretation of 'it'

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

3.4 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are likely to be restricted to calculation questions and should be shown by the abbreviation ECF or *conseq* in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

3.5 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited (eg fizix) **unless** there is a possible confusion (eg defraction/refraction) with another technical term.

3.6 Brackets

(…..) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

3.7 Ignore / Insufficient / Do <u>not</u> allow

'Ignore' or 'insufficient' is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

'Do **not** allow' means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

3.8 Significant figure penalties

Answers to questions in the practical sections (7407/2 – Section A and 7408/3A) should display an appropriate number of significant figures. For non-practical sections, an A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the **final** answer in a calculation to a specified number of significant figures (sf). This will generally be assessed to be the number of sf of the datum with the least number of sf from which the answer is determined. The mark scheme will give the range of sf that are acceptable but this will normally be the sf of the datum (or this sf -1).

An answer in surd form cannot gain the sf mark. An incorrect calculation **following some working** can gain the sf mark. For a question beginning with the command word 'Show that…', the answer should be quoted to **one more** sf than the sf quoted in the question eg 'Show that X is equal to about 2.1 cm' – answer should be quoted to 3 sf. An answer to 1 sf will not normally be acceptable, unless the answer is an integer eg a number of objects. In non-practical sections, the need for a consideration will be indicated in the question by the use of 'Give your answer to an appropriate number of significant figures'.

3.9 Unit penalties

An A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the correct unit for the answer to a calculation. The need for a unit to be quoted will be indicated in the question by the use of 'State an appropriate SI unit for your answer'. Unit answers will be expected to appear in the most commonly agreed form for the calculation concerned; strings of fundamental (base) units would not. For example, 1 tesla and 1 Wb m^{-2} would both be acceptable units for magnetic flux density but 1 kg m^2 s^{-2} A^{-1} would not.

3.10 Level of response marking instructions

Level of response mark schemes are broken down into three levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are two marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

Determining a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level. ie if the response is predominantly level 2 with a small amount of level 3 material it would be placed in level 2.

The exemplar materials used during standardisation will help you to determine the appropriate level. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

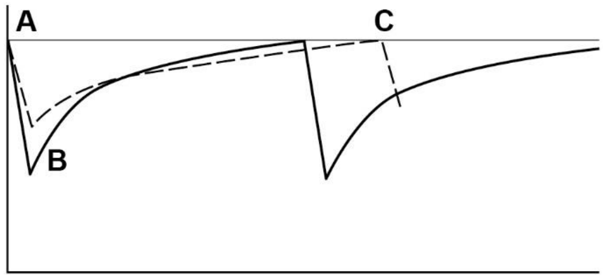
You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme.

An answer which contains nothing of relevance to the question must be awarded no marks.

Question	Answers	Additional comments/Guidance	Mark	AO
01.1	torque $_1$✓ = <u>moment of</u> inertia $_2$✓ × <u>angular</u> acceleration $_3$✓	$_1$✓ $_2$✓ $_3$✓ 2 marks any two of $_1$✓ $_2$✓ $_3$✓ 1 mark Do not accept 'inertia' for 'moment of inertia' or ‘acceleration’ or ‘rotational acceleration’ for ‘angular acceleration’ If = or equals, or × or multiplied by, is missing or in wrong place: 0 marks Condone ‘proportional to’ for ‘=’.	2	2 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.2	Refers to $I = \sum mr^2$ in symbols or in words ✓ (Plate) **A** because more of the mass is distributed at a greater distance from the axis of rotation (than for plate **B**)✓	Look for I depending on radius/distance of (constituent) masses squared. Do not accept ‘$I = mr^2$’ alone **A** alone is not enough. There must be a statement about the mass distribution or spread.	2	2 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.3	decrease in speed from ω_A not as much / ω_B greater ✓ curved line (from new **B**) with smaller initial gradient up to ω_A ✓	 Slope of new **AB** can be ignored unless it is shown with a much smaller gradient. Position of new C can vary, but shape of cycle must be similar to original. Do not mark beyond candidate’s first **C**	2	2 × AO3

Question	Answers	Additional comments/Guidance	Mark	AO
01.4	Either: For same energy, in $E=\frac{1}{2}I\left(\omega_A^2-\omega_B^2\right)$, (new) ω_B will be greater for greater I and same E ✓ **OR** For same motor torque, greater I means smaller angular acceleration, so smaller initial slope for **BC** ✓	Accept same idea expressed in other ways, eg initial (rotational kinetic) energy greater, so less fall in speed for same energy loss (during punching). If **B** to **C** curve starts at same ω_B as Figure 2 with smaller initial gradient, and their **B** to **C** takes longer time to ω_A allow: For same motor torque, greater I means lower angular acceleration, so longer time for **B** to **C**	1	1 × AO3

Total			Mark
Total			**7**

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	$T = F \times r$ applies with some explanation of r in this context. ✓ force on pedal will vary/down force greater than up force/operator cannot keep force constant **OR** Component of force varies with position/rotation of crank **OR** Distance/radius of line of action of F from axle varies (as crank moves) ✓	Simply quoting $T = F \times r$ is not enough for MP1 2nd mark: accept: use of the term 'dead centre' 'Radius varies' is not enough Accept idea that moment of force/torque varies with position of crank	2	2 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	Relates angular impulse to change in angular momentum and to torque × time ✓ If angular momentum/angular velocity reduced to zero in short time, high torque results (which will strain mechanism) ✓	Accept answer using formulae: Application of $T\Delta t = \Delta(I\omega)$ with understanding of symbols shown Accept $Tt = \Delta I\omega$ Angular impulse does not have to be seen if $Tt = \Delta I\omega$ is correctly applied $\Delta I\omega$ is fixed, t small, so T high (enough to strain mechanism)	2	2 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
02.3	$\alpha = 13.8 \div 15.0 = 0.92$ (rad s^{-2}) ✓ Calculates I using $T = I\alpha$ giving 0.84 (kg m^2) ✓ OR $\theta = \frac{1}{2}(\omega_1 + \omega_2)t = \frac{1}{2} \times 13.8 \times 15 = 103.5$ (rad) Calculates I using $\frac{1}{2}I\omega^2 = T\theta$ giving 0.84 (kg m^2)	$I = \frac{0.77}{0.92} = 0.84$ kg m^2 ECF for incorrect α $I = \frac{0.77 \times 103.5}{95.2} = 0.84$ kg m^2 ECF from incorrect θ (e.g. use of max speed instead of average speed)	2	2 × AO2

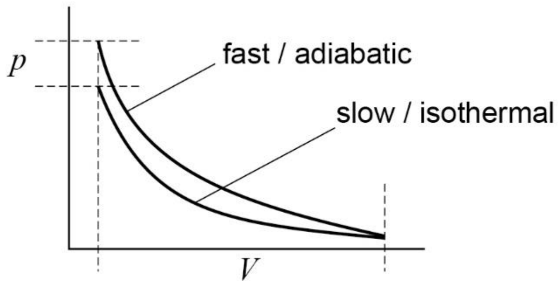
Question	Answers	Additional comments/Guidance	Mark	AO
02.4	Equates 3.1 N m to 'sharpening' torque + frictional torque ✓ calculates sharpening torque and equates to $F \times r$ to give $F = 9.7$ N ✓	'sharpening' torque = 2.33 N m Condone ECF for MP2 (but do not give MP1) if total torque is added to frictional torque, but neither MP1 nor MP2 given for ignoring friction torque or using *only* frictional torque. Expect to see $F \times 0.24 = 3.87$ giving $F = 16.1$ N No marks for $F \times 0.24 = 0.77$ giving $F = 3.2$ N No marks for $F \times 0.24 = 3.1$ giving $F = 12.9$ N	2	2 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
02.5	calculates any power by multiplying any **corresponding** $T \times \omega$ from any graph ✓ does this at $\frac{1}{2}\omega_0$ for 2 or 3 of the motors ✓ shows **F** is only motor to satisfy $\frac{2}{3}P_{max}$ criteria ✓ **OR** calculates any power by multiplying any **corresponding** $T \times \omega$ from any graph ✓ calculates max power output of required motor as $1.5 \times 52 = 78$ W ✓ Shows only motor **F** satisfies this at $\frac{1}{2}\omega_0$ ✓	For **E**: $P_{max} = 120 \times 0.43 = 52$ W $\frac{2}{3} \times 52 = 35$ W For **F**: $P_{max} = 150 \times 0.52 = 78$ W $\frac{2}{3} \times 78 = 52$ W For **G**: $P_{max} = 90 \times 0.64 = 58$ W $\frac{2}{3} \times 58 = 39$ W	3	3 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	energy supplied/transferred/input to system/gas (by heating/heat transfer) ✓ **OR** energy transferred/lost/output from system/gas (by cooling heat transfer) if Q negative	Do not allow 'heat' in place of 'energy' Do not accept 'heat transferred' on its own Accept ‘heat energy supplied’ but not ‘heat supplied’.	1	1 × AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	Tick against top line only $-10.8 \quad 0 \quad 10.8$		1	1 × AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	Use of $p_1 V_1^{1.4} = p_2 V_2^{1.4}$ ✓ Giving $p_2 = 2.32 \times 10^6$ (Pa) ✓ T_2 (= $\frac{p_2 V_2 T_1}{p_1 V_1}$) = 710 (K) ✓	‘use of’ means by substitution or manipulation to make p_2 the subject of the equation eg $p_2 = p_1 \left(\frac{V_1}{V_2}\right)^{1.4}$ seen Accept γ for 1.4. $T_2 = \frac{2.32 \times 10^6 \times (3.19 \times 10^{-9}) \times 293}{1.05 \times 10^5 \times 2.91 \times 10^{-8}}$ ECF for T_2 using their p_2	3	3 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	Slow change means internal energy remains (nearly) constant due to energy loss by heat transfer **OR** Slow change means (nearer to) isothermal change ✓ (Therefore) the work done would be lower because the area under the graph would be lower **OR** the work done would be lower because the pressures are lower✓ (Therefore cyclist is not correct)	Allow reverse argument from fast change perspective. Accept answers where shown in a diagram:  Alternative MP2: smaller (average) p for same ΔV will give less W	Max 2	2 × AO3

Total			**7**

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr>
<td>04</td>
<td>The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer. Guidance provided in section 3.10 of the ‘Mark Scheme Instructions’ document should be used to assist marking this question.
<table>
<tr><th>Mark</th><th>Criteria</th></tr>
<tr><td>6</td><td>All three areas (as outlined alongside) covered with at least two aspects covered in some detail.
6 marks can be awarded even if there is an error and/or parts of one aspect missing.</td></tr>
<tr><td>5</td><td>A fair attempt to analyse all three areas. If there are several errors or missing parts then 5 marks should be awarded.</td></tr>
<tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.</td></tr>
<tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr>
<tr><td>2</td><td>Only one area discussed, or makes a partial attempt at two areas.</td></tr>
<tr><td>1</td><td>One of the three areas covered without significant error.</td></tr>
<tr><td>0</td><td>No relevant analysis.</td></tr>
</table>
</td>
<td>The following points are likely to be present.

First two bullets: differences at A and B
1. Corners rounded at B on real cycle. Reason: valves take finite time to open and close.
2. Cooling cannot occur at constant volume in real cycle. Reason: piston would have to stop/cooling takes finite time.
3. Heating cannot occur at constant pressure in real cycle. Reason: heating cannot be (precisely) controlled.
4. Max pressure is lower in real engine. Reason: e.g. incomplete combustion

Third bullet: region C
5. Real engine needs induction and exhaust strokes/ pumping loop.
6. In theoretical cycle same air used repeatedly (so needs no pumping loop).
7. In ideal cycle air only is taken through cycle (repeatedly)/gas is ideal.
8. Upper line is exhaust, lower line is induction.

Fourth bullet: why efficiency less
9. Area of loop is smaller for real engine, so less work done per cycle/indicated power.
10. Area of pumping loop has to be subtracted from main loop, reducing work done.
11. Friction between moving surfaces/between piston & cylinder/in bearings has to be overcome.</td>
<td>6</td>
<td>5 × AO1

1 × AO2</td>
</tr>
</table>

		12. Energy is expended in driving oil and water pumps, opening and closing valves, overcoming fluid viscosity etc. 13. In real cycle expansion & compression are not adiabatic. Reason: heat transfer takes place to cooling medium during these strokes 14. Calorific value of fuel cannot be completely released/ Fuel may not be completely burnt. Accept other reasonable answers in lieu (eg variation in γ during expansion and compression).		

Total			**6**

Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	0.60 OR 60%✓	Condone 0.6 (1 sf) $\eta = \frac{(730 - 290)}{730} = 0.60$ $\eta = \frac{16.0 - 6.4}{16.0} = 0.60$	1	1 × AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	Calculates P_{OUT} from engine 1 and calculates Q_C ✓ Uses Q_C from engine 1 as Q_H for engine 2 and calculates P_{OUT} from engine 2 ✓ Compares total output power and overall efficiency of **Figure 9** and **Figure 10** engines and concludes that they are the same so student is not correct ✓	$\eta_1 = 220 \div 730 = 0.30$ $P_{OUT1} = 0.30 \times 16.0 = 4.8$ kW $Q_C = 11.2$ kW $\eta_2 = 220 \div 510 = 0.43$ $P_{OUT2} = 0.43 \times 11.2 = 4.8$ kW Allow ECF for MP2 from MP1 Total $P_{OUT} = 9.6$ kW Overall η for 2 stages = $9.6 \div 16 = 0.60$ Do not allow an ecf for MP3 Evidence can be seen on **Figure 9** and **Figure 10** but answer must make clear comparisons. If calculations are correct, but more than 2 sf is used, then answers will be slightly greater than 9.6 kW and greater than 0.60. Do not accept a comment that the student claim is correct as this answer arises from conclusions drawn from poor sf considerations.	3	3 × AO3

Total			**4**	