A-level
PHYSICS
7408/3BC

Paper 3 Section B Engineering physics

Mark scheme

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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.

No student should be disadvantaged on the basis of their gender identity and/or how they refer to the gender identity of others in their exam responses.

A consistent use of 'they/them' as a singular and pronouns beyond 'she/her' or 'he/him' will be credited in exam responses in line with existing mark scheme criteria.

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

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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	(No external torque acts so) conservation of angular momentum applies $_1$✓ Ang. momentum of turntable equal and opposite to ang. momentum of propeller so turntable rotates anticlockwise/in opposite direction to propeller $_2$✓ $I_T > I_P$ so turntable rotates more slowly than propeller $_3$✓	Can be expressed in symbols eg $I_T \omega_T = -(I_P \omega_P)$ For $_2$✓ and $_3$✓ there must be correct statement and reason. Do not allow $\text{mass}_T > \text{mass}_P$ instead of $I_T > I_P$	3	AO1 ×1 AO2 ×2

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>01.2</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 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>
Measuring angular speeds (ω_1 and ω_2) (Both required for full)
1A.Use of optical or magnetic sensor
2A. with datalogger/data-recorder/ more detail
1B. use of video /mobile phone/stroboscope
2B. with more detail
1C. stopwatch and fiducial mark
2C. and finding time for several revs

Other measurements (Both required for full)
3. Mass of dropped mass AND Distance of (centre of) mass to centre of turntable/axis of rotation
4A. using top pan balance/scales
4B. using vernier callipers or ruler

Calculation (Three points for full; one/two for partial)
5. idea that rev s^{-1} must be converted to $rad\ s^{-1}$
6A. M of I of mass = mr^2 ($= I_{mass}$)
7A. ($I_{mass} + I$) $\omega_2 = I\ \omega_1$
6A & 7A. $I = \frac{mr^2\omega_2}{(\omega_1 - \omega_2)}$ OR substitute $\omega_1\ \omega_2\ m$ and r into above equations to find I

A graphical method might be described, eg
6B. Plot $\frac{\omega_1}{\omega_2}$ against r^2 for various r

7B. $I = \frac{m}{\text{gradient}}$
</td><td>6</td><td>AO1 ×1
AO2 ×3
AO3 ×2</td></tr>
<tr><td>Total</td><td></td><td></td><td>9</td><td></td></tr>
</table>

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	Use of total area under graph = 2.52 rad ✓ Valid attempt at calculating the area in **Figure 4**✓ ω_{max} = 0.87(1) rad s^{-1} ✓	MP2 eg: 2.52 = [½ (1.5 × 0.35)] + [½ (ω_{max} + 0.35) × 1.2] + [½ × 3.5 × ω_{max}] Must show calculation answer to 2 sf or more.	3	AO2 ×3

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	Idea that $T = I\alpha$ must be used at times where there is a peak of the Figure 5 graph. ✓ Calculates one value of $I\alpha$ at the time during any of the 3 accelerations where I is at a peak ✓ Calculates the maximum values of torque for all three acceleration and shows overall maximum value is at t = 2.1 s ✓	MP1: must show that they have considered using peak at 2.1 s and at least one other peak 1st acctn: $T_{max} = 12200 \times 0.35/1.5 = 2850$ N m (at 0.65 s) 2nd acctn: $T_{max} = 10400 \times (0.87 - 0.35)/1.2 = 4510$ Nm at 2.1 s 3rd acctn: $T_{max} = 12800 \times -0.87/3.5 = -3180$ N m (at 5.1 s) Allow ± 200 kg m^2 on I Allow use of $\omega_{max} = 0.9$ rad s^{-1} giving 2nd acctn $T_{max} = 4760$ N m 3rd acctn $T_{max} = 3320$ N m Where comparisons are made condone answers that miss × 10^3 factor in I For MP3, condone a calculation of max values of torque for both accelerations up to t = 2.7 s with a mention of the negative acceleration from t = 2.7s.	3	AO2 ×2 AO3 ×1

Question	Answers	Additional comments/Guidance	Mark	AO
02.3	ALTERNATIVE 1 at times near 2.7 s: $T = I\alpha$; I is slightly smaller and α is constant so that torque is slightly smaller OR $P = T\omega$; T is slightly smaller but ω is increasing (as α positive). ✓ Both statements together with conclusion that P_{max} must occur at a time other than 2.1 s ✓ ALTERNATIVE 2 Calculates power at $t = 2.1$ s ✓ Calculates power at a different time and concludes that P is greater at this time ✓	Answer does not have to be fully quantitative eg between 2.1 s and 2.7 s the torque decreases slightly because I decreases slightly and α remains constant. But ω increases greatly to a max at 2.7 s, $P = T\omega$ so P greater at 2.7 s. Ignore friction torque Condone POT errors when a comparison is made.	2	AO3 ×2
Total			**8**	

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	MAX 4 from: • Attempts to find area of large loop • Subtracts area of small loop • Shows suitable scaling factor • Uses 4 cycles s^{-1} • correctly calculates indicated power using their values. 592 W ✓ (cao)	eg counting small squares 157 – 9 squares = 148 squares scaling factor of $0.10 \times 10^{-3} \times 0.1 \times 10^{5} = 1.0$ J per square 148 J × 1.0 = 148 J If counting 'large' squares: (6.5 - 0.5) squares × $0.50 \times 10^{-3} \times 0.50 \times 10^{5}$ gives 150 J Accept approximating to triangles cycles s^{-1} = 4 (as it is double acting at 2 rev s^{-1}) indicated power = 148 × 4 = 592 W ± 30 W	5	AO1 ×1 AO3 ×2 AO2 ×2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	Input power = $6.44 \times 10^{-4} \times 18.0 \times 10^{6} = 11.6 \times 10^{3}$ W ✓ Output power = $T\omega = 39.0 \times 2 \times 2\pi = 490$ W ✓	Correct answers only Accept 1.2×10^{4} W or 12000W Condone working not shown provided answers are correct.	2	AO1 ×2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	MAX 2 from: • Power is developed for only about half of the stroke $_1$✓ • Maximum pressure is very much lower than in a petrol engine $_2$✓ • The fuel is not compressed before ignition $_3$✓ • Pumping loop/negative work is large compared to work output loop $_4$✓ • The speed of the engine is very low $_5$✓ • Difficulty in lubricating cylinder so friction likely to be high $_6$✓ • Calorific value of fuel is low $_7$✓	Allow for other sensible reasons eg efficiency from 03.2 is only about 4% Do not accept simple references to 'low efficiency' or 'less efficient' For $_6$✓ Do not accept 'more friction' without a reason	2	AO3 ×2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	Tick in 2nd box ✓ Overall efficiency is the product of mechanical efficiency and thermal efficiency.		1	AO1 ×1

Total			10

Question	Answers	Additional comments/Guidelines	Mark	AO
04.1	All three terms stated correctly: Q: energy transferred/supplied **to** system (by heating) ✓ ΔU: **increase** in internal energy (of system) ✓ W: work done **by** system ✓	2 terms correct for 1 mark 3 terms correct for 2 marks Allow 'gas' in place of 'system' For Q: Accept 'heat energy supplied' but not 'heat supplied'. Do not allow 'heat' in place of 'energy' Do not accept 'heat transferred' on its own Do not accept 'thermal energy' or 'heat energy' on its own. For ΔU: 'of system' does not have to be seen	Max 2	AO1 ×2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	($Q = W + \Delta U$) where W (is provided by electrical input and) is –ve since W is done on the system ✓ $Q = 0$ because system is insulated ✓ $0 = -W + \Delta U$ and so internal energy of the room increases. ✓	MP2 and MP3: reasons must be given	3	AO3 ×2 AO2 ×1

Question	Answers	Additional comments/Guidelines	Mark	AO
04.3	Cold sink / cold reservoir / cold space drawn and labelled with line connecting to engine with downwards arrow ✓	Accept 'low temperature' for 'cold' Do not allow 'cold/low temperature source' 'Sink' or 'heat sink' on its own is not enough, but give the mark if T_C is written in or near implying cold temperature.	1	AO1 ×1

Question	Answers	Additional comments/Guidelines	Mark	AO
04.4	Use of maximum theoretical efficiency = $\frac{T_H - T_C}{T_H}$ ✓ efficiency < 100 % as $T_C > 0$ (in practice) OR efficiency can only be 100 % when T_C is 0 K which is impossible ✓	Condone following argument for max 1 mark: $\eta = (Q_H - Q_C)/Q_H$ OR $= \frac{W}{Q_H}$ so $\eta < 1$ (or $< 100\%$) ✓ as there must be some Q_C to cold sink (in a practical case)✓	2	AO1 ×2
Total			**8**	