A-level
PHYSICS
7408/3BC

Paper 3 Section B Engineering physics

Mark scheme

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2 1 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 not 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. i.e. 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	(The M of I decreases) because more mass closer to axis of rotation ✓$_1$ $I\omega$/angular momentum constant since no external torque ✓$_2$ since I decreases, ω must increase ✓$_3$	For ✓$_1$ must have the idea of mass distribution around axis of rotation. Do not accept answers which give only decrease in radius as reason for lower M of I. For ✓$_2$ condone answers which do not mention the condition of no external torque. ✓$_3$ cannot be awarded if conservation of rotational kinetic energy used.	3	AO1.1a × 3
01.2	$I_1\omega_1 = I_2\omega_2$ $\quad \omega_1 = 4.3$ rad s^{-1} ✓	Accept the answer 4.3 rad s^{-1} if no working shown.	1	AO2.1f × 1
01.3	Finds time for one rotation ✓ Divides 1.2 by time AND gives answer for complete rotations, not rounded up. ✓ OR Finds angle turned through in 1.2 s ✓ Divides by 2π AND gives answer for complete rotations, not rounded up. ✓	time for 1 rotation = $2\pi/14.2 = 0.442$ s $1.2/0.442 = 2.7$ rotations/turns/somersaults. OR Angle turned through = $14.2 \times 1.2 = 17.04$ rad $17.04/2\pi = 2.7$ rotations Expect to see 2 complete rotations/turns/somersaults. For MP2 give CE for time or angle from MP1	2	AO2.1f × 2

Question	Answers	Additional comments/Guidance	Mark	AO
01.4	Any 2 from: • build up a greater initial angular speed around the bar ✓ so reaches a greater height/will rotate faster in tuck ✓ • release at a greater angle from the horizontal ✓ so will rise to greater height giving more time for somersaults ✓ • get into tuck position earlier/get out of tuck position later ✓ so turning for more time ✓ • get into tighter tuck position ✓ reducing I_2, and increasing ω_2 ✓	Any 2 statement ✓ and correct reason ✓ scores 2 marks for each.	4	AO3.1b × 4
Total			**10**	

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	Equates initial E_p to linear E_k and rotational E_k ✓ Substitutes values and uses $V = r\omega$ ✓ Calculates V to give $0.51\ \text{m s}^{-1}$ ✓	$9.2 \times 10^{-2} \times 9.81 \times 0.5 = (½ \times 9.2 \times 10^{-2}\ V^2) + (½ \times 8.6 \times 10^{-5} \times \frac{V^2}{0.005^2})$ $V = 0.51\ \text{m s}^{-1}$ Some substitution of data must be seen for MP2 Do not allow MP3 for no consideration of linear E_k Give 1 mark if $mgh = ½I\omega^2$ used with answer $0.51\ \text{m s}^{-1}$	3	AO2.1f or AO2.1h × 3

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	Calculates α from $\alpha = T/I$ ✓ Attempts to use any appropriate equation(s) of motion (for angular motion) ✓ Substitutes into equation(s) of motion and calculates θ ✓	$\alpha = (8.3 \times 10^{-4}) / 8.6 \times 10^{-5} = 9.65\ \text{rad s}^{-2}$ or $9.7\ \text{rad s}^{-2}$ $\theta = 145 \times 10 - ½ \times 9.7 \times 10^2 = 967\ \text{rad or } 970\ \text{rad}$ MP2: $\omega_2{}^2 = \omega_1{}^2 + 2\alpha\theta$ is not enough on its own as there are two unknowns. MP2: Quoting appropriate formula(e) is not enough. There must be some attempt at substituting the data.	3	AO2.1b × 3
Total			**6**	

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr><td>03.1</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 in marking this question

Level 3 (5–6 marks)
6 marks: both areas of the question are covered (i.e. calculations and explanations) with all efficiencies calculated correctly and at least two of points 7,8,9.
5 marks: both areas covered but with one or two minor errors in calculations or explanations.

Level 2 (3–4 marks)
4 marks: all efficiencies calculated correctly with no explanation of usefulness of efficiencies OR a good attempt at calculating efficiencies and some explanation given of usefulness of efficiencies.
3 marks: Both areas covered partially or one area covered reasonably well but not fully. E.g may only be able to calculate correctly 2 of the three required efficiencies and give no explanation of their usefulness.

Level 1 (1–2 marks)
Student is likely to make one or two calculations (e.g input power and one efficiency) at any speed, but not likely to be able to explain the usefulness of efficiency.

0 marks
The student shows inadequate understanding of the graphs. Formulae may be quoted from the Formulae Booklet or from memory, but the student is unable to apply their meaning to the question.</td><td>Numerical answers:
1. Peak brake power occurs at (6200 to 6600) rev min^{-1}
2. Input power = 136 kW
3. Overall efficiency = 0.29
4. Thermal efficiency = 0.35
5. Mechanical efficiency = 0.84
6. Friction power = 7.5 kW

General points:
7. Relates thermal efficiency to how well the calorific value of fuel is converted into work/power inside the engine.
8. Relates mechanical efficiency to work/power used in overcoming friction/viscosity inside engine and work/power to operate valves, water/oil pumps etc.
9. Overall efficiency gives an idea of how well energy in fuel is converted into useful work output.

If student uses peak <u>indicated</u> power points 1 to 5 become
1. Peak power occurs at (7200 to 7600) rev min^{-1}
2. Input power = 150 kW
3. Overall efficiency = 0.26
4. Thermal efficiency = 0.32
5. Mechanical efficiency = 0.80
Do not allow marks at Level 3.</td><td>6</td><td>AO3.1a ×1

AO1.1a × 3

AO2.1h × 2</td></tr>
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Question	Answers	Additional comments/Guidance	Mark	AO
03.2	Links two quantities from Figure 4 at speeds above 7000 rev min^{-1} ✓ Gives reason for not running engine at speeds above 7000 rev min^{-1} ✓	Examples of points expected for MP1: • brake power drops whilst input power continues to increase (as shown by fuel consumption curve) • brake power drops whilst indicated power flattens off • indicated power flattens off while fuel consumption increases Do not accept: the brake power gets less with no reference to other power(s). MP2: any of overall, thermal or mechanical efficiency decreases, or efficiency decreases. friction or friction power increases at high engine speeds breakdown of lubrication and/or greater work done against viscosity at high engine speeds. Do not accept: damage to engine may occur - unless backed up by reason relating to friction/friction power. .	Max 2	AO3.1b ×1 AO2.1g ×1
Total			**8**	

Question	Answers	Additional comments/Guidance	Mark	AO
04.1	Attempt to determine area under graph ✓$_1$ Use of correct scaling factors to find area in J ✓$_2$ Calculates area to be between 22 J and 25 J ✓$_3$ Finds work needed to drive at least one nail into wood using $W = F \times s$ ✓$_4$ Concludes that expansion roughly matches energy to drive nail D ✓$_5$	Eg counting squares 9 large sq $\times 2 \times 10^5 \times 10 \times 10^{-6} = 18$ J 67 small sq $\times 2/25 = 5.4$ J Total 23(.4) J Accept 11 to 12½ large sq giving 22 to 25 J W for D $= 420 \times 0.050 = 21.0$ J Nail E needs much more W, others need less W. OR F = (wd by gas) ÷ length and compares with forces in Table 2. For ✓$_5$ do not accept 'closest' answer unless answer for w.d by gas ≥ work needed to drive nail. ECF for ✓$_5$ for their calculated area	5	AO1.1b × 1 AO3.1b × 4
04.2	Isothermal process/expansion requires (relatively) long time for expansion to take place OR Process/expansion must occur slowly ✓$_1$ Reason: isothermal needs energy transfer (Q) for temperature/internal energy to remain constant ✓$_2$ nail fired in less than ⅓ second so expansion very fast/not enough time for energy transfer ✓$_3$ (so process cannot be isothermal)	For ✓$_2$ do not credit energy must be supplied without reference to temperature or internal energy. For ✓$_3$ must relate time to the data in the question.	3	AO3.1a × 1 AO1.1a × 2
Total			**8**	

Question	Answers	Additional comments/Guidance	Mark	AO
05.1	The efficiency is 50% when the kelvin temperature of the hot source is twice the kelvin temperature of the cold sink. ✓		1	AO1.1a × 1

Question	Answers	Additional comments/Guidance	Mark	AO
05.2	Identifies $Q_H = 3 \times W$ and $Q_C = Q_H - W$ ✓ In reverse $COP_{ref} = Q_C / W$ Leading to $COP_{ref} = 2$ ✓	MP1 can be awarded for $Q_H - Q_C = 0.33Q_H$ or $Q_C = 0.67Q_H$ Give credit for substituting numbers in equations eg $W = 1$ $Q_H = 3$, $Q_C = 2$ OR $W = 33$ $Q_H = 100$, $Q_C = 67$ Accept working shown on a diagram Accept working using temperatures T_H T_C with numbers substituted eg $T_H = 300$ (K), $T_C = 200$ (K) No credit for simply quoting formulae from Formulae Booklet.	2	AO1.1b × 2

Total			3