AQA

A-LEVEL
PHYSICS
7408/3BC

Paper 3 Section B Engineering physics

Mark scheme

June 2020

Version: 1.0 Final

2 0 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. 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	Sum of all constituent masses × their radius/distance from the axis squared	Allow Σmr^2 with m defined as small mass or constituent mass or particle at a radius r and Σ explained. Condone: 'from the axis' missing Condone: a quantity expressing a body's tendency to resist angular acceleration/change in angular speed	1	AO1.1a ×1
01.2	E_P lost (by falling mass) = E_K pulley + E_K mass ✓ $0.5Mgh = ½(0.5M)v^2 + ½(0.5MR^2)\ \omega^2$ Cancel 0.5 and M and substitute $\omega = \frac{v}{R}$ for ω gives $gh = ½v^2 + ½v^2 = v^2$ ✓ use of $v^2 = u^2 + 2as$ giving $v^2 = 2ah$ ✓ substitutes $v^2 = 2ah$ in $gh = v^2$ (so $a = 0.5g$) ✓ OR $0.5Mg - F = 0.5Ma$ ✓ Torque = $I\alpha$ $F \times R = (0.5MR^2)\alpha$ ✓ (giving $F = 0.5\ MR\alpha$) and substitute $\alpha = a/R$ leading to $F = 0.5Ma$ ✓ Substitute for F in $0.5Mg - F = 0.5Ma$ (gives $a = 0.5g$) ✓	1st mark for equating E_P lost by mass to E_K gained by **both** mass and pulley. Accept this step in words or symbols 2nd mark for $gh = v^2$ 3rd mark for v^2 in terms of h 4th mark for combining correctly (to get $a = 0.5$g) OR with F or other letter as tension in string: 1st mark for Newton's 2nd law applied to mass in words or symbols 2nd mark for accelerating torque equation 3rd mark F in terms of a 4th mark for substituting to get $a = 0.5g$ *Note: $\alpha = a/R$ is not in the spec, but students may know it and use this route.* Give ECF if M is used for the falling mass in place of $0.5M$	4	AO2.1d ×4 L2M ×3

Question	Answers		Additional comments/Guidance	Mark	AO
01.3	**Route 1**	**Route 2**	WTTE	Max 3	AO3.1b ×3
	M of I spoked pulley is greater ✓$_1$	M of I spoked pulley is greater ✓$_1$	For ✓$_3$ and ✓$_4$ marks in route 2		
	Reason given for greater M of I but must have reference to distribution or spread of mass about axis ✓$_2$	Reason given for greater M of I but must have reference to distribution or spread of mass about axis ✓$_2$	$0.5M(g - a) = F$ $0.5M(g - a)R = I\alpha$ $0.5Mg = a(0.5M + I/R^2)\ a$ If I increases, a decreases.		
	Greater proportion of E_P loss given to pulley OR lower prop to E_K of falling mass ✓$_3$	Presents valid argument relating I to α ✓$_3$			
	v of mass in same time will be lower so acceleration lower ✓$_4$	$\alpha = a/R$ (with α less) so acceleration of mass is less OR wheel turns through fewer rotations in same time so point on rim moves less distance so acceleration less ✓$_4$			

Total			8

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	No (net) external torque acts (on the system) ✓	Do not accept force for torque	1	AO1.1a ×1
02.2	$I_A\ \omega_A + I_B\ \omega_B = (I_A + I_B)\ \omega$ ✓ (taking clockwise as positive) $(7.2 \times 95) + (11.5 \times -45) = 18.7\omega$ $\omega = (+)8.9\ \text{rad s}^{-1}$ ✓ clockwise ✓	Accept answers with anticlockwise taken as positive. 1st mark for equation or substitution, but condone any incorrect sign for angular velocity. 2nd mark: answer to at least 2 sf 3rd mark for direction, ECF provided direction agrees with sign in calculated answer and sign convention used. 3rd mark is not an independent mark and is contingent on some attempt at calculation using angular momentum	3	AO2.1f ×3 L2M ×2
02.3	Attempts to use Angular impulse $= Tt = \Delta(I\ \omega)$ ✓ Clutch C: $600\ t = 7.2 \times (95 - 8.9) = 620$ (N m s) $t = 1.03$ s OR $\alpha = (95 - 8.9)/t$ $600 = I\ \alpha = 7.2\ (95 - 8.9)/t$ $t = 1.03$ s Clutch D: $320\ t = 7.2 \times (95 - 8.9)$ $t = 1.93$ s ✓ (for either or both times calculated) Compares correct times with 1s < t < 2s and concludes both clutches satisfy criterion. ✓	1st mark: attempts to use idea of angular impulse Mark not given for just quoting formula. 2nd mark: correct time(s) calculated for either or both clutches OR torques calculated for 1 s and/or 2 s [620 Nm and 310 Nm] 3rd mark: correct conclusion based on correct times for both clutches OR based on comparing calculated torques for 1 and 2 s with data in Table 2 Answers may be worked out using shaft B: $T \times t = 11.5 \times (-45 - 8.9) = (-)620$ N m s	3	AO3.1a ×3 L2M ×2

		Give full marks if 9 rad s^{-1} is used, giving angular impulse = 619 N m s t for clutch C = 1.03 s t for clutch D = 1.93 s		

Total			**7**

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr><td>03</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>There is a response to both bullet points in the question. Student quotes or uses points A B C 11 and 12 in words or symbols and have 7 or more of detail points 1-10 covering all three powers.</td></tr>
<tr><td>5</td><td>There is a response to both bullet points in the question. Mark as for 6 above. Answers will not be as confident or detailed as for 6 marks, or answers may not be expressed using scientific terminology.</td></tr>
<tr><td>4</td><td>The student describes how to determine at least 2 of powers A, B, C with detail points for each. They may be able to give one of the efficiencies. They should have at least 7 of points 1 to 12. Answers show more confidence than for 3 marks.</td></tr>
<tr><td>3</td><td>Student describes how to determine at least 2 powers. They will have 5 points or more from 1 to 12 .They may miss out efficiency formulae altogether,or get them wrong.</td></tr>
<tr><td>2</td><td>Student includes 3 or 4 of points 1 to12, relating detail points 1 to 10 to the appropriate power formula.</td></tr>
<tr><td>1</td><td>Makes any 2 of points 1 to 12.</td></tr>
<tr><td>0</td><td>No sensible statements made.</td></tr>
</table>

Marks not awarded for simply quoting formulae from Data booklet.

</td><td>

Likely answer points:

<u>1st bullet</u>
Measurements/info needed and how obtained
A input power from c.v. × fuel flow rate
1. measure volume of fuel used in given time
2. by using reservoir/measuring cylinder and stopclock
3. find/look up calorific value of fuel; accept c.v. is known

B indicated power from area of indicator diagram x cycles s^{-1}
4. need cylinder pressures and corresponding volumes
5. take an indicator diagram / p–V diagram
6. using sensors (data logger + computer + software)
7. determine area of indicator diagram with method
8. measure speed from tachometer <u>and</u> × ½

C brake (output) power from $P = T\omega$
9. torque on output shaft using dynamometer and engine speed using tachometer
10. multiply tachometer reading by 2π

Note: no credit for formulae simply stated as they are in formulae booklet.
<u>2nd bullet</u>
11. thermal efficiency = indicated power/input power

12. mechanical efficiency = brake power/indicated power

(Note: these formulae are not in the formulae booklet)

</td><td>6</td><td>AO1.1a ×3

AO2.1g ×1

AO3.2b ×2</td></tr>
<tr><td>Total</td><td></td><td></td><td>6</td><td></td></tr>
</table>

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>04.1</td><td><table><tr><th>Process 1</th><th>Process 2</th><th></th></tr><tr><td>constant pressure</td><td>isothermal</td><td></td></tr><tr><td>constant volume</td><td>adiabatic</td><td></td></tr><tr><td>constant pressure</td><td>adiabatic</td><td></td></tr><tr><td>constant volume</td><td>isothermal</td><td>✓</td></tr></table></td><td>Tick only in cell indicated.</td><td>1</td><td>AO1.1a ×1</td></tr>
<tr><td>04.2</td><td>Attempt to apply $p_1V_1 = p_2V_2$ or pV = constant ✓
$(1.00 \times 10^{-4} + 2.80 \times 10^{-4} - V)\ 1.01 \times 10^5 =$
$1.83 \times 10^5 \times (2.80 \times 10^{-4} - V)$ ✓
Leading to $V = 1.57 \times 10^{-4}\ m^3$ ✓</td><td>1st mark for equating pV before to pV after plunger pushed in - in words or symbols or numbers
2nd mark for correct substitution in either p_1V_1 or p_2V_2 or both
3rd mark for answer</td><td>3</td><td>AO2.1h ×3
L2M ×2</td></tr>
<tr><td>04.3</td><td>steeper curve ✓
vertical line ✓
(as shown alongside)</td><td>Allow vertical line that does not come right down to end of isothermal compression line</td><td>2</td><td>AO1.1b ×1
AO2.1d ×1</td></tr>
<tr><td>04.4</td><td>(In isothermal process) (for internal energy to remain constant) energy transfer must take place ✓
If change is slow there is enough/sufficient time (for energy transfer) ✓</td><td>Statements showing the First Law applied to an isothermal compression in symbols are not enough unless symbols are explained.</td><td>2</td><td>AO1.1a ×2</td></tr>
</table>

Total			8	

Question	Answers	Additional comments/Guidance	Mark	AO
05.1	(For 2nd law of thermodynamics to apply...) Engine must operate between hot and cold reservoirs ✓ And must reject some energy to cold reservoir ✓ (Meaning W cannot equal Q_H)	accept hot and cold spaces / hot source and cold sink / high and low temperatures Accept for 2nd mark: For 100% efficiency T_C would have to be 0 K (which is impossible)	2	AO1.1a ×2
05.2	175 ºC = 448 K and 30 ºC = 303 K and ✓$_1$ $\eta = \frac{T_H - T_C}{T_H}$ ✓$_1$ $= \frac{448 - 303}{448} = 0.32$ ✓$_2$ ($\eta = \frac{W}{Q_C + W}$ so $Q_C = \frac{W}{\eta} - W$) $Q_C = \frac{2.9}{0.32} - 2.9 = 6.2$ MW ✓$_3$ 6.2 MW < 6.4 MW so claim is not true ✓$_4$ Alternatives for 3rd and 4th marks: For Q_C =6.4 MW, $\eta = \frac{2.9}{2.9+6.4} = 0.31$ ✓$_3$ Actual $\eta > 0.31$ so Q_C has to be < 6.4 MW so claim not true ✓$_4$ OR	1st mark for converting to K and giving thermal efficiency equation 2nd mark for calculating efficiency 3rd mark for another relevant calculation 4th mark for a comparison leading to a conclusion regarding claim. This is not an independent mark. e.g. 4th mark: claim is not true (based on ideal engine) because 6.2 MW < 6.4 MW ✓$_4$ OR accept: claim is true; for real engine η will be (considerably) less, so energy available for greenhouse heating will be/is likely to be higher than 6.4 MW If temperatures <u>not</u> changed to K condone giving ECF for marks ✓$_3$ and ✓$_4$: $\eta = \frac{175 - 30}{175} = 0.83$ $Q_C = \frac{2.9}{0.83} - 2.9 = 0.6$ MW ✓$_3$ 0.6 < 6.4 so claim not true ✓$_4$	4	AO1.1b ×1 AO3.1b ×3 L2M ×3

	input power = $\frac{2.9}{0.32}$ = 9.1 MW input power needed for company claim = 2.9 + 6.4 = 9.3 MW ✓$_3$ $9.1 < 9.3$ so claim not true ✓$_4$			

Total			**6**