AQA

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 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.

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	ID details
01.1	2.9 rev s^{-1} equivalent = $2\pi \times 2.9$ rad s^{-1} = 8.2 rad s^{-1} OR $I = 2\,E_k/\omega^2$ OR correct substitution in $E_k = ½\,I\,\omega^2$ ✓ leading to $I = 6.2 \times 10^{-2}$ kg m^2 ✓	1st mark for correct conversion rev s^{-1} OR rearranging energy equation in terms of I OR correct substitution in $E_k = ½\,I\,\omega^2$ 2nd mark for correct answer. Do not allow final answer to 1 sig fig e.g. 0.06	2	1.1b × 2 L2M × 2
01.2	I depends on how mass is distributed about axis (of rotation) For arms, screw and punch same mass is/point masses are closer to axis than the steel balls (making M of I lower) ✓ I depends on r^2 so I changes greatly for small change in in r ✓	Allow 'other parts' or 'other components' if it is clear this means screw, punch and arms	2	2.1a × 1
01.3	$\alpha = \frac{2 \times \pi \times (0 - 2.9)}{0.089} = -205$ rad s^{-2} ✓ Attempt to use $\omega_2^2 = \omega_1^2 + 2\alpha\theta$ or $\theta = \omega_1 t + ½\,\alpha t^2$ or $\theta = ½(\omega_1 + \omega_2)t$ ✓ giving $\theta = 0.81$ rad ✓	Condone missing sign or α given as positive Accept 200 rad s^{-2} If α positive, 2nd mark for attempt to use $\omega_2^2 = \omega_1^2 - 2\alpha\theta$ or $\theta = \omega_1 t - ½\,\alpha t^2$ or $\theta = ½(\omega_1 + \omega_2)t$ ✓ ECF for value of ω used in 01.1	3	2.1e × 3 L2M × 3
01.4	($I = 2\,mr^2$ and $E_k = ½\,I\,\omega^2$) Increasing y by 15% gives new $I = 1.15^2 \times$ original I (or 1.32) ✓ Increasing R by 15% increases I by 1.15^3 (or 1.52) ✓ Second option gives greater increase in I, and E_k also increased (by same ratio). ✓	Accept answers without calculation: I prop to y^2 ✓ I prop to R^3 ✓ For <u>same</u> % increase in y or R, I and hence E_k increases more by increasing R ✓ *Note:* $E_k = m\,r^2\,\omega^2 = 4/3\,\pi\,R^3\rho\,r^2\,\omega^2$ for each ball	3	3.1a × 3 L2M × 2?

01.5	✓ against N m s		1	1.1b ×1
Total			**11**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
02.1	Work done ✓		1	1.1b

02.2	**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.** **Mark** / **Criteria** 6: There is a response to all 3 bullet points in the question. There is a good understanding of the function of a flywheel, and why the torque varies markedly in a diesel engine. Student can relate the answer to the two graphs. Includes 6 or more answer points from the list alongside 5: There is a response to all 3 bullet points in the question covering 6 answer points. Answers will not be as confident or detailed as for 6 marks, or answers may not be expressed using scientific terminology. 4: The student gives five or more answer points covering at least two of the bullet points. 3: At least four pertinent statements. They may show little understanding of the electric motor but should be able to give some reasons why a diesel engine needs a flywheel. 2: Two or three pertinent statements taken from the list of likely answer points. 1: One pertinent statement. 0: No sensible statements made. Other sensible and applicable points can be accepted in lieu of any of those alongside.	Likely answer points: 1st bullet 1. Electric motor's constant torque means smooth motion/doesn't need smoothing/doesn't need a flywheel 2. motor's output torque matches the described load 2nd bullet 3. relates force/pressure on piston to torque 4. force on piston varies over one cycle (as pressure in cylinder varies) 5. Torque = *Fr* and effective *r* varies as crank rotates 6. -ve torque: when work is being done **on** (the gas in) the engine (during induction, comp, exhaust strokes) 7. Zero torque when con rod and crank are in line/at top and bottom dead centres 8. This happens at crank angles which are multiples of π 3rd bullet 9. Diesel engine's (varying torque) will give uneven/jerky motion/cause stalling 10. Flywheel acts as energy store 11. Flywheel absorbs energy on power/expansion stroke 12. and gives up energy on other parts of cycle 13. Flywheel speeds up on expansion stroke 14. and slows down during other strokes. 15. The greater the M of I of flywheel, the smoother the motion 16. If no flywheel engine will stall/become very uneven/jerky 17. The greater the M of I of flywheel, the longer engine will take to speed up, slow down/stop 18. Because machine has low M of I it will not be able to store energy itself or smooth the motion.	6	1.1a x 3 2.1a x 3

Total			7

Question	Answers	Additional Comments/Guidance	Mark	ID details
03.1	$p_A V_A = p_B V_B$ $V_B = \frac{1.0 \times 10^5 \times 9.0 \times 10^{-2}}{2.2 \times 10^5}$ ✓ $(= 4.1 \times 10^{-2}\ m^3)$	The mark is for attempt to use Boyle's Law with correct numbers substituted.	1	1.1b × 1 ? or 2.1f × 1 L2M × 1
03.2	Use of $\frac{V_B}{T_B} = \frac{V_C}{T_C}$ ✓ OR Use of $\frac{p_A V_A}{T_A} = \frac{p_C V_C}{T_C}$ ✓ Leading to $T_C = 425\ K$ ✓	Allow ECF from **03.1** Accept any correct application of $pV/T =$ constant 426 K if $4.09 \times 10^{-2}\ m^3$ used for V_B At least 3 sig fig answer must be seen	2	1.1b × 2 ? or 2.1f × 1 L2M × 2
03.3	(see table below)	1st mark for either italicised answer correct including sign 2nd mark for both italicised answers correct including sign Calculations might show *W* for **D** → **A** $= p\Delta V = 1.0 \times 10^5 \times (13.0 - 9.0) \times 10^{-2}\ J = 4000\ J$	2	2.1b × 2
03.4	1st Law applies/must be obeyed OR $Q = \Delta U + W$ ✓ (for isothermal process) $\Delta U = 0$ so $Q = W$ ✓	1st mark for any reference to First Law in words or equation. 2nd mark for stating $\Delta U = 0$ (in isothermal process) and showing $Q = W$	2	2.1f × 2

Table for 03.3:

Process	Work *W*/J	Heat transfer *Q*/J
A → **B**	-7100	-7100
B → **C**	4000	*14000* ✓
C → **D**	10 300	10 300
D → **A**	*- 4000* ✓	-14 000

03.5	Claim is correct as Net work = 3200 J ✓$_1$ η = 3200/ 10300 = 0.31 or 31% ✓$_2$ $\eta\text{max} = \frac{425-295}{425}$ = 0.31 or 31% ✓$_3$ OR $\eta\text{max} = \frac{420-295}{420}$ = 0.30 or 30%	Alternative for 1st mark: Net work = area of loop in Fig 3 = 6.5 squares × 500 J = 3250 J allow ± 250 J If student tots up their *W* column in Table 1 correctly for their values, award the 1st mark point ✓$_1$ (or if they use the area of the cycle correctly calculated) Also award ✓$_1$ for 3200 J even if it does not agree with their Table 1. If they have been awarded ✓$_1$ for net work, and divide this value by 10300, give the 2nd mark point ✓$_2$ If they calculate the max theoretical efficiency correctly give ✓$_3$ **Then if they have ✓$_1$, ✓$_2$ and ✓$_3$:** If there is no concluding statement award 2 marks If the concluding statement is incorrect for their efficiencies award 2 marks If their concluding statement is correct for their efficiencies award 3 marks If they only get the max theoretical efficiency, award 1 mark. If 420 K has been used allow argument that efficiencies are not (quite) the same	3	3.1b ×1 3.1a × 2

03.6	Isothermal processes are impossible/difficult to achieve ✓ Because engine would have to run (very) slowly **Or** perfect conducting material used ✓ OR Economiser will not store/transfer energy effectively ✓ because it will lose heat to surroundings ✓ **Or** unless it has large/have large surface area **Or** because it will not be perfectly insulated Accept other sensible suggestions and corresponding reasons	Answer should relate to the real engine based on ‘this cycle’. Do not allow problems common to all heat engines e.g. ignore ’friction’ and simple statements relating to ‘heat loss to surroundings’. Give 1 mark if student spots that Work/power output is very small for size of engine 1 mark if they back this up.	2	3.1a × 2

Total			**12**

Question	Answers	Additional Comments/Guidance	Mark	ID details
04.1	Heat pump takes energy/heat from cold space/sink/reservoir/surroundings (and gives to hot space) ✓ (Electrical) energy needed by heat pump is less than (electrical) energy needed by conventional dryer by energy/heat taken from cold space ✓ OR this means more energy given to hot space/dryer per unit of electrical energy input than for a conv. dryer	Accept answers as equations: Conv. dryer $Q_H = W_1$ In heat pump $Q_H = W_2 + Q_C$ or WTTE ✓ So for same Q_H, $W_2 = W_1 - Q_C$ ✓	2	1.1a ×1? 2.1a ×1
04.2	Converts temperatures to K (278 K, 293 K and 433 K) ✓ Calculates COP_{garage} for 278 K and 433 K = 2.8 and calculates $COP_{kitchen}$ for 293 K and 433 K = 3.1 ✓ COP $_{kitchen}$ is greater so lower energy input/running cost needed for the kitchen/20°C ✓	1st mark for temperatures in K 2nd mark for calculating COPs or for argument using $T_H/(T_H - T_C)$ showing COP less for lower cold space temperature 3rd mark for relating higher COP to lower energy input/running cost for given Q_H or more Q_H per kWh. For 2nd mark condone temperatures not converted to K giving $COP_{kitchen}$ = 1.14 COP_{garage} =1.03. Award 3rd mark as above. Condone 20°C space to identify kitchen	3	3.1a × 3
Total			**5**	